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Michael E. Auer
David Guralnick
Istvan Simonics *Editors*

# Teaching and Learning in a Digital World

## Proceedings of the 20th International Conference on Interactive Collaborative Learning – Volume 2

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# Preface

ICL2017 was the 20th edition of the International Conference on Interactive Collaborative Learning. This interdisciplinary conference aims to focus on the exchange of relevant trends and research results as well as the presentation of practical experiences in Interactive Collaborative Learning and Engineering Pedagogy. This conference is at the same time the annual conference of the "International Society of Engineering Pedagogy (IGIP)."

ICL2017 has been organized in cooperation with the Óbuda University from September 27 to 29, 2017, in Budapest, Hungary.

This year's theme of the conference was "Teaching and Learning in a Digital World."

Again, outstanding scientists from around the world accepted the invitation for keynote speeches:

- **Dale A. Martin**, CEO of Siemens Hungary,
- **Michael K. J. Milligan**, ABET Executive Director and CEO, USA,
- **András Benedek**, Professor of Education at Budapest University of Technology and Economics, and DSc of the Hungarian Academy of Sciences, and
- **Greet Langie**, Vice-Dean of the Faculty of Engineering Technology at KU Leuven, Belgium.

Since its beginning this conference is devoted to new approaches in learning with a focus on collaborative learning and engineering education.

We are currently witnessing a significant transformation in the development of education. There are two essential and challenging elements of this transformation process that have to be tackled in education:

- the impact of globalization on all areas of human life,
- the exponential acceleration of the developments in technology as well as of the global markets and the necessity of flexibility and agility in education, and
- the necessity of a closer cooperation between the industry, academia, and governmental organizations, especially in Engineering Education.

Therefore, the following main themes have been discussed in detail:

- Collaborative Learning,
- Project-based Learning,
- New Pedagogies with a focus on Engineering Pedagogy,
- K-12 and Pre-university programs,
- Learning Culture, Diversity & Ethics,
- Lifelong Learning and Academic-Industry Partnerships,
- Mobile Learning Environments Applications,
- New Learning Models and Applications,
- Online Environments and Laboratories,
- Game-based Learning,
- Computer-aided Language Learning (CALL),
- Entrepreneurship in Engineering Education,
- Real-world Experiences and Pilot Projects, and
- Ubiquitous Learning Environments, Platforms, and Authoring Tools.

The following submission types were accepted:

- Full Paper, Short Paper,
- Work in Progress, Poster,
- Special Sessions, and
- Roundtable Discussions, Workshops, Tutorials.

All contributions were subject to a double-blind review. The review process was very competitive. We had to review 569 papers. A team of about 150 reviewers did this terrific job. My special thanks go to all of them.

Due to the time and conference schedule restrictions, we could finally accept only the best 190 submissions for presentation.

Our conference had again more than 270 participants from 47 countries from all continents.

ICL2018 will be held in Kos Island, Greece, and ICL2019 in Bangkok, Thailand.

Michael E. Auer
ICL General Chair

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# The Use of Software to Create E-Learning Courses on Technical Subjects at University

Leonid Leonidovich Khoroshko(✉), Peter Alexandrovich Ukhov, and Alexey Leonidovich Khoroshko

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**Abstract.** This article proposes an integrated approach regarding the use of different software for practice-oriented training in engineering disciplines. Emphasis is placed on the formation of a unified educational space for training in engineering disciplines. An approach to the integration of a large number of application software solutions based on the "Moodle" distance learning shell was developed. Examples include the use of the proposed approach for "Machine Parts" and "Theory of Machines and Mechanisms" technical training courses in terms of practice-based learning.

**Keywords:** Engineering education · e-Learning · 3D modeling

## 1 Introduction

Currently, the design and development of new aviation and space technologies performed by the world market leaders is done by means of multinational teams of developers. Designers and technicians may be located in different cities and countries. The team-work is performed in a single design environment based on a digital prototype of the product using specific development tools. A large number of computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) systems are being used widely in the course of development. The educational process of the research universities should be based on scientific work. In fact, many scientific studies are carried out with the help of CAD/CAE systems. Enterprises of aviation and space industries, which are the training customers, are interested in further cooperation with the graduates, who have experience and skills in working with CAD/CAE systems.

Various CAD/CAE systems have their own characteristics that determine the processes of training courses development and their integration into a single educational space of the university. Therefore, the development of training courses for engineering disciplines, within which must deal with specific engineering problems, has a number of features and issues that need to be addressed. These problems include the formation of a unified educational space, application of the different systems integration, application of the development issues and the integration of existing content, taking into account the subsequent use in the practice-oriented training.


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## 2 Software Solution for the Formation of a Single Training Environment

One problem of major research university educational space organization is associated with the heterogeneity of the educational environment. As a rule, several learning management systems are used in major universities simultaneously. Each of these systems has its own characteristics. For example, there are two own e-learning systems in our university: Personalteacher 2.0 [1] and training system for mathematical disciplines CLASS.NET [2]. The possibility of systems that have been developed by external suppliers and development communities are used widely as well: Moodle [3], eFront, REDCLASS, e-learning server 4G. These systems have a large amount of educational content to be used with minimal processing.

In addition to the possibilities of educational systems built-in editors, eAuthor and CourseLab tools for course development are used widely. A set of courses selected according to SCORM standard specifications is being formed. However, the practice of using different training systems showed that in spite of the support of the said standard, the courses containing unique multimedia objects (digital prototypes of products) do not always work correctly in a variety of distance training systems.

In accordance with the requirements of national legislation regarding personal information the information on students and teachers is stored in the university management system [4], which meets all security requirements. In addition, there are several electronic library systems. The thematic groups of the university on various activities are organized via social networks. In such circumstances, consolidation of educational statistics and integrated management of educational content becomes quite a challenge.

On order to solve the above problem, the protocols for the exchange of information between the main learning management systems and library systems have been developed. Information about the users from the protected corporate systems is transferred to the main e-learning system in a partially impersonal form. “Moodle” program shell was chosen as the primary storage system of educational statistical data. Own authentication methods (authorization plugin), methods of enrollment into courses (enrollment plugin), blocks (blocks plugin) and modules (activity module) for the management of educational process have been developed for this system. Training systems provide the exchange of information with the “Moodle” software via modules which are integrated in appropriate courses. The module sends the information about the students into the connected educational system through a secure communication channel and then receives training statistics from the connected system in the form of a final rating. This approach enables the integration of different learning systems and external applications into a single learning environment. Electronic library systems are integrated through the blocks of training systems. A specific unit is designed for each library system that allows sending information about users to the system and receiving the necessary statistics from the library system.

The advantage of this approach is as follows: a smooth transition of students and teachers to the requested resources without the need for additional procedures for registration and authentication. The synergistic effect of the combined system has been achieved as a result of the work performed. The attendance of the thematic systems and library resources has increased. Optimization of the user registration process will allow to use the different training systems, depending on the specific application. In addition, the students have access to the transition to cloud services used for engineering computations and application servers in seamless mode due to the existing approach. In this situation, maintaining manageability of the education system is an important factor, since all statistics are stored in a single database, and is available for administrative staff.

By virtue of this approach it is possible to solve the problem of using multiple CAD/CAE systems based on multiple platforms in a training course. All resources are unified on the basis of “Moodle” software in a single training course. This course ensures that students do not just study the educational material; they also have practice-oriented training in the respective CAD/CAE systems based on the application server or a cloud service. All statistics are stored in a single system, and this fact provides a significant simplification of the activities of teachers and supervisors.

In addition, this approach solves the problem of personal data protection through well-defined standards of information exchange between the host training system and other related systems. The impersonal information relating to students is being transmitted to the connected system, which significantly increases the security of the information. The problems associated with the protection of information including commercial value have been solved also through a flexible system of differentiation of students’ access rights to external information systems and knowledge databases.

The proposed approach has allowed to abandon the registration of users completely in a large number of related systems that required constant attention of the staff to the presence of errors in the personal data of students even with automation of the components. The effectiveness of the proposed solutions has been confirmed on the basis of two parameters - reducing of the maintenance costs and costs on audit of all electronic training complex databases and reducing of the access time to educational resources for students. In some cases, reduction of time was significant - from five days to a few seconds.

## 3 Examples of Interactive Content for Practice-Based Learning

Our university uses a large number of CAD/CAE systems, but two of them - Solid Works [5] and Autodesk Inventor - are used widely for the development of materials for training courses and practice-based learning. One of the benefits of these environments is the ability to perform further analysis of the models developed in other CAE systems and the presence of own add-ins for engineering analysis. In addition, the data can be transferred to the CAM system for printing 3D models of various objects.

One of the solutions in the development of technical training was the use of the Autodesk Inventor 3D-modeling environment. On one hand, the actual models of technical objects enable the students to visualize their goals and functions. On the other hand, the model contains all the basic parameters of the original, so you can use it for the organization of independent practical work of students. In addition, the most successful solutions can be created on a 3D printer as a product demonstration.

"Machine parts" e-learning course may serve as an example. 3D-model showing different types of connections, gears, chain drives and other technical devices were developed for this course. These models are integrated into the material for lectures; their viewing is possible with the free Autodesk utility for viewing of 3D-models called Design Review. The theoretical course material is formed using "Moodle" standard development tools.

In addition to working with the theory, students can work with these models through the application server on the basis of product lifecycle management (PLM) of Geolus Search environment. This makes it possible to expand the possibilities of studying technical courses significantly and fill them with practical activities. According to the finished models (Fig. 1), students perform calculations for power and numerical experiments. This allows to develop the skills of practical and designing works.

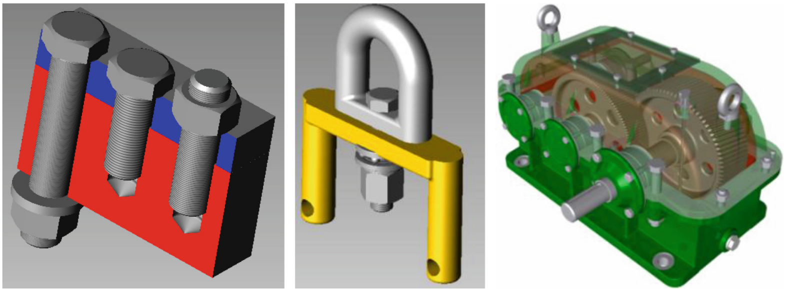

**Fig. 1.** Models of the compounds, Model for virtual laboratory works for the "Machine parts" course

Each task is a mini-project with a large number of possible solutions. In addition, the teacher introduces additional data that the project team should take into account in the subsequent work into the PLM system at certain stages of the mini-project implementation. Thus, it prepares the students for the real work with these systems and instills teamwork skills and agile approaches.

Due to the fact that the models are parameterized, each team of students (from three to five persons) receives a unique challenge with its own characteristics, implementation procedure (different input data for the product life cycle) and specific effects. Thus, the generation of large number of the unique tasks for project teams is being performed. In this case, due to the lack of possibility of making automatic changes in PLM system being used, the main focus of the teacher's work switches to this point.

The educational videos used to illustrate the operation of various technical objects, such as gears and transmissions, gearboxes, friction mechanisms and other technical devices were created using Autodesk Inventor software. While viewing the lecture material the students have the opportunity to "touch" the real technical objects, and this ability enhances the viewing experience greatly. Visual illustration of the lectures is not the only use of 3D-models in the theoretical course. The virtual laboratory work was developed on their basis: the gear assembly, the determination of gear parameters, the calculation of the friction coefficient on the end of the nut, etc. [6]. The guidelines regarding their implementation and the types of reporting were created for virtual laboratory works; this saves time for teacher during training in the laboratory and allows to work with each student individually. In some cases, it is possible to abandon the costly labs with accurate or expensive equipment without losing the quality of education.

One of the elements of practice-based learning is to develop the gear in the PLM environment in the process of studying the "Machine parts" course. Teamwork is carried out with a clear division of roles - the designers and technologists. Thanks to the PLM environment data, it is possible to assess the contribution of each participant to the overall project and the degree of elaboration of the product as a whole. The most successful projects are made by 3D printing.

The ability to perform measurements on the 3D-objects created expands the scope of the models application significantly. Autodesk Inventor software allows to create technical objects on the basis of earlier calculations, thus allowing to visualize the result. For example, this may be done to obtain a ready three-dimensional reducer from a source file in MS Excel format containing the calculations of the strength and defining all the parameters for the construction of the object including technological advices for the manufacturing of the parts.

An additional feature of Autodesk Inventor software is the ability to create animations from 3D-objects. This can improve the visualization of technical courses significantly. For example, a set of laboratory works used to study the structure, kinematics and dynamics of mechanisms has been developed for the "Theory of mechanisms and machines" course. This set allows the students to acquire the skills of working with the schemes of the mechanisms (Fig. 2), learn the basics of the mechanisms development, conduct dynamic analysis, etc.

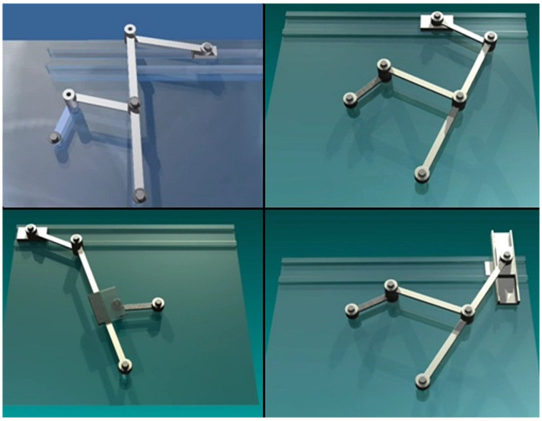

**Fig. 2.** Models for the virtual laboratory works on the "Theory of mechanisms and machines" course

The possibilities of Autodesk Inventor software and other CAE systems allow the use the 3D-models for more complex calculations. At the same time, the use of PLM systems and a set of multiple CAD/CAE systems in one course makes it possible to operate in seamless mode. “Moodle” course workspace is organized for students, which is used to contain all the elements of practice, making the transition to a given system or application server.

## 4 Conclusions

The problem of the formation of the uniform educational environment for studying technical courses on the basis of “Moodle” is solved. The proposed model of the modules development for training courses capable of exchanging information using established protocols with CAE and PLM systems and application servers has proven to be effective. The reduction in the time for the registration of students in the various education systems, reduced maintenance costs, and cost of audit of the databases for complex e-learning systems has been achieved.

Using Autodesk Inventor software has increased the visibility of technical courses significantly. The tools for organizing teamwork of students in interactive mode and conditions close to real work were developed. Thanks to virtualization capabilities, students can work on the university servers, and teachers can monitor the results easily as well as improve the methodology for assessing the practice-oriented projects.

## References


1. Creating a model of corporate information management system in order to meet the requirements of human capital assets. In: Instruments and systems. Control, monitoring, diagnostics Moscow “Nauchhelitizdat” Publishing House, pp. 52–54 (2010)
2. Kibzun, A.I., Naumov, A.V., Mkhitarian, G.A.: Aspects and technologies of development of mathematical disciplines distance learning CLASS.NET. Mod. Inf. Technol. Inf. Edu. **1**(11), 153–156 (2015)
3. Ukhov, P.A., Lomakin, A.L.: Technology of distance learning in college [Fuel and Energy Complex], p. 180. Moscow humanistic Technical Academy, Moscow, MHTA Publisher (2010). Monograph
4. Sypalo, K.I., Sidorova, Y., Kozorez, D.A., Medvedskii, A.L., Popov, S.S.: Certificate of state registration of the software for the computer No. 2011619456, 13 December 2011
5. Tikhonov, K.M., Tishkov, V.V.: Modeling the dynamics of complex systems based on modern IT-technology. In: Proceedings of the XVII International Symposium Dynamic and technological problems of mechanics of structures and continuous media, vol. 2, Moscow, “TP-pechat” LLC, pp. 154–160 (2011). named after Gorshkov, A.G.
6. Khoroshko, L.L., Sukhova, T.S.: The use of virtual and remote laboratory exercises in engineering education with e-Learning. In: Proceedings of 15th International Conference on Interactive Collaborative Learning and 41st International Conference on Engineering Pedagogy, Austria, Villach. IEEE Catalogue Number: CFP1223R-USB (2012). ISBN 978-1-4673-24267

# The Digital University Agreen U How to Build an Innovative Knowledge Sharing and Learning Project in Agribiosciences? Case Study

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**Abstract.** The Agronomic, Veterinary and Forestry Institute of France (Agreenium), representing eighteen French public research and higher education institutions in Agribiosciences decided to create a unique portal to the digital university in Agribiosciences, agreen U (https://agreenium.fr/u/accueil). Its objective is to encourage digital education in this sector to accompany the evolution of teaching practices but also contribute to the strengthening of the international visibility of French research and higher agricultural and veterinary education, and to develop the international attractiveness of the French training offer in the scope of Agribiosciences. The paper explores the identification of functional specifications necessary to attract learners in a such e-learning ecosystem by an international comparative analysis of fifteen universities and institutes and their online courses offers. The paper concludes that we can propose a framework of the functional specifications dedicated of an e-learning project.

**Keywords:** Agribioscience · Digital university · Functional specifications e-learning · Open education

## 1 Introduction

In France, online education and e-learning are only developing. Recent official reports recommend that e-learning and online training should be supported in public education, higher education and professional training. Online education is seen as a mean to support the economy, offers better opportunities and access to education to young generations, promotes and support lifelong training, and develops the European and international dimension of the French higher education and research system. The French government has recently provided funds to education and research institutions to support online education projects as stated in Refs. [1, 2].

On the other hand, France plays a very important role in the international trade of agri-food products and the French research in Agribioscience benefits from a good international visibility in this field. And in fact, the French offer in terms of e-learning in Agribioscience is almost absent on the Web.


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In 2015, the government created Agreenium - the Agronomic, Veterinary and Forestry Institute of France - a structure that federates the eighteen main institutions of research and higher education in Agribioscience.

Agreenium decided to launch a unique portal for the education amongst its members: the online university in Agribiosciences, agreen U (https://agreenium.fr/u/accueil). Its objective is to encourage digital education in this sector to accompany the evolution of teaching practices but also contribute to the strengthening of the international visibility of research and higher agricultural and veterinary education in France, and to develop the international attractiveness of the French training offer in the scope of Agribiosciences.

In this short paper, we have concentrated our reflexion on how we have built the functional specifications for such a project from a comparative analysis of the e-learning offers around the world, in order to clear a methodology which can be able to equip an e-learning project.

## 2 Materials and Methods

### 2.1 The Set of Examples

The comparative study has been done on selected top educational institutions in Agribiosciences (Davis, Wisconsin, Laval, Wageningen,…) from two official ranking lists

**Table 1.** List of selected universities

| Rank | Name of the university |
|---|---|
| 1 | Davis University |
| 2 | University of Wisconsin Madison |
| 3 | University of California, Berkeley (UCB) |
| 4 | Wageningen WUR |
| 5 | AgroParisTech |
| 6 | Institut Mines Telecom |
| 7 | COMUE example of Paris-Saclay |
| 8 | Cornwell University |
| 9 | Université de Laval (Québec) |
| 10 | ETH Zurich |
| 11 | University of Reading |
| 12 | University de Strasbourg (UNISTRA) |
| 13 | Agropolis |
| 14 | University of Florida |
| 15 | Paris Sciences Lettres (PSL) |
| 16 | Ecole polytechnique fédérale de Lausanne (EPFL) |
| 17 | University of Tokyo |
| 18 | Boston University |
| 19 | Arizona State University |

[3, 4], and others universities which are a complete strategy about the e-learning development (Institut Mines Télécom, UNISTRA, EPFL).

The objectives of the study is to identify international actors of the sector of digital training and education, and evaluate the level of progress of Agreenium's international competitors in terms of online training offer and promotion. This study would allow to identify strategies, offers and good practices. The analysis methodology focused on websites and platforms of selected universities to evaluate the online ecosystem, the training offer and users' experience.

Fifteen examples of e-learning offer from the universities (see Table 1). We have selected French but also others international universities or education organisation in the domain of Agribiosciences but not only. In fact, the example of Mines Telecoms institute, a major engineers' school in France and in Europe is presented because his action plan in the e-learning and its promotion is very significant.

## 2.2 The Methodology of Data Gathering

Many academic publications deal with the conditions of satisfaction of students about the online courses. Some results show institutions how to improve learner satisfaction and further strengthen their e-Learning implementation [5]. Several criteria of the positive opinions learners are identified for example the flexibility, the content elements enhancing their motivation, (3) the ability to communicate easily with the instructor, instant feedback, and access to the course materials easily as stated Ref. [6]. The conditions of attractiveness of the offer of online courses for students don't seem to be a priority for analysis. However, it determines a significant part of the success of them and their attractiveness [7].

We have tried to demonstrate how the different e-learning platforms have built their success as well as on the "content" and the "container" and develop strategy of promotion to attract learners. The data collection has been done from the examination of the different websites of the platforms. We distinguish different criteria (see Table 2) below to characterize the attractiveness of an e-learning platform, which are weighted. The weighting was determined according to the importance attached to certain criteria by the steering committee Agreenium members regarding e-learning project in the field of agribiosciences. For example, the weight of the "MOOC number" criterion in this area is heavier than the "number of online courses" criterion in other areas.

**Table 2.** Criteria's list of selection for the comparative analysis

| |
|---|
| NUMBER OF PROPOSED ONLINE TRAINING |
| Number of MOOC (Agro BioSciences theme) (coef2) |
| Number of online Master (Agri BioSciences theme) (coef2) |
| Number of professional certificates (Agri BioSciences theme) (coef2) |
| Number of other on-line training courses (Agri BioSciences theme) (coef1) |
| Number of online courses (All themes) (coef3) |
| IMPORTANCE FOR ONLINE TRAINING ON THE WEB SITE OF THE ENTITY |
| Presence in the main menu (coef2) |
| Presence in the sub-menu (coef2) |
| Presence in home page (coef3) |
| Number of dedicated pages (coef2) |
| Mention of programs under development? (Coef1) |
| QUALITY OF ELEMENTS INSTALLED TO CONVINCE |
| Existence of an "online training" category (coef2) |
| Existence of a "guidance system" in online training (coef1) |
| Presentation of the training (teachers, what you will learn,…) (coef1) |
| Accessible online training extract (coef1) |
| Contact: Access to an online chat / Contact button (coef1) |
| Testimonials (coef1) |
| Applynowbutton / Requestinfo (coef1) |
| Questions and answers (coef1) |
| Existence of elements to convince the relevance of online training (coef3) |

# 3 Results and Discussion

## 3.1 What Does the Mapping of the Online Courses Offer Say?

The study have been led to identify leader platforms for users' experience and the promotion of the online training offer. The proposed mapping is discriminant (see Fig. 1). University of Florida dominates the ranking in terms of number of online courses with the exception of the Institut Mines Télécoms, the French entities studied do not present on-line training courses (Agropolis - 1 MOOC only). Wageningen and the University of Laval (Québec) are distinguished by the importance given on their website to the different online courses. Davis University and the Institute of Mines Télécom (with the information present on FUN) are present by the quality of the information available to convince students. American universities seem to be ahead of their European counterparts about the quality of information provided to be attractive (but not necessarily on the importance given to digital training). The cartography underlines the good balance achieved by Wageningen and the Institute of Mines Télécom. These institutions represent a good synthesis between the rich offer of online courses and the promotion of it, and the commitment of the learners, by a building student engagement and belonging.

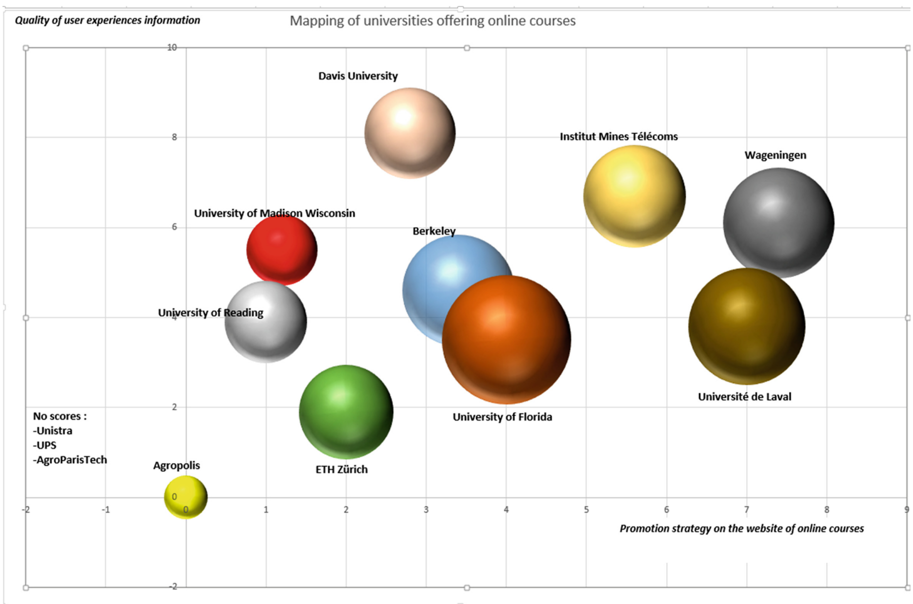


**Fig. 1.** Mapping of universities offering online courses

### 3.2 Functional Translation for the Project of the Digital University Agreen U

From this comparative analysis of online course sites, we were able to identify main functionalities for agreen U project. The different good practices represent a model of simple functional specifications for a project of e-learning. If we propose a synthesis, the tree structure appears as very important for the information structuration and its analysis shows a clear way of identification and representation of online training versus "traditional" education, in the best sites, a section specifically dedicated to research exits. For the users/learners, the ergonomics of the website to work on the online courses is very important so in the best propositions, clear navigation, short main menu, image navigation seems to propose a real added value with a coherent use of rich media (videos…). As well, the good practices show different aspects of interactivity with the possibility of the courses 'customisation, the chat and hot line and the previews of trainings. Finally, one last of these good practices to attract learners is the commitment with the possibility of commenting on courses between learners and with teachers and the sharing of functions. These features are described below.

**A clear presentation of the learning ecosystem of the project.**
This ecosystem must be simple, complete and showing the international action of Agreenium with interactive mapping for example and present the different actions of each member of Agreenium which represents the rich resource of the consortium in agribiosciences.

**Easy access of Agreenium resources.**
The main functionality must be the use of the same access codes for the all resources and online spaces of the ecosystem agreen U.

**The community management option.**
Open or closed forums with the management of member's profiles are necessary to propose an added value for the learners and teachers. These functionalities are Chat, mailing list, social networks, and groups of discussion.

**Mapping and data visualising.**
The agreen U project must provide maps and data visualising system showing all students and the work progress, their research subjects, maps by countries, themes, or skills, and courses.

**News services.**
The service must make it possible to identify all the relevant news for the user according to his profile by a recommendation system.

**Customization services.**
The customization of courses and contents allows the navigation by profile including tracking tools to feed the customer relationship management system.

# 4 Conclusion

## 4.1 The Functional Specifications Answering to the Expectations of Agreenium

Online education is seen as an important opportunity and meets high expectations from member institutions of Agreenium. However, these institutions often lack resources, skills or funds to develop projects. Agreenium is seen to have an important role in developing online projects, and bringing skills and international visibility.

This analysis is a work in progress and did not considered other important criteria, such as number of users (students) per year, per month, per day of studied examples. This choice is led by the members of Agreenium convinced by the project of agreen U is a good digital project for cooperation between all of them. The first steps of the project was focused on the international offer in e-learning in terms of system of specifications and not in terms of use. However, the study results about the e-learning as stated in Ref. [8] revealed principles and modalities for achievement of agronomic education. Students are involved in teaching and learning and teachers became their real partners in an interactive educational environment.

The expectations for Agreenium about the ecosystem agreen U are:

- Associate the skills amongst its 18 members to work together on common projects,
- Support the development of online education and distance learning,
- Provide tools and processes for cooperation and experience sharing.

With the analysis, the Mines Télécoms Institute develops similar missions to those of Agreenium in a different field. His example shows that a competitive training offer on the Web is possible in France. So, we have been able to propose a model of simple functional specifications for a project of e-learning able to answer to the expectations and requirements of Agreenium and, other organization which would like to launch such project.

## 4.2 Outcomes and Perspective

The main outcome consist to the online digital university agreen U which represent an integrated platform of e-learning, resources and community management (see Fig. 2) launch in February 2017. The agreen U strategy will be able to answer to the following issue: matching needs and service proposals. The next steps of this study is to analyse the users and their behavior concerning agreen U resources in comparison with others European and international e-learning systems. That is crucial for the development of agreen U. The online university should be able to propose innovative services in order to stay attractive for the Agribiosciences communities and beyond, after the attractive launch.

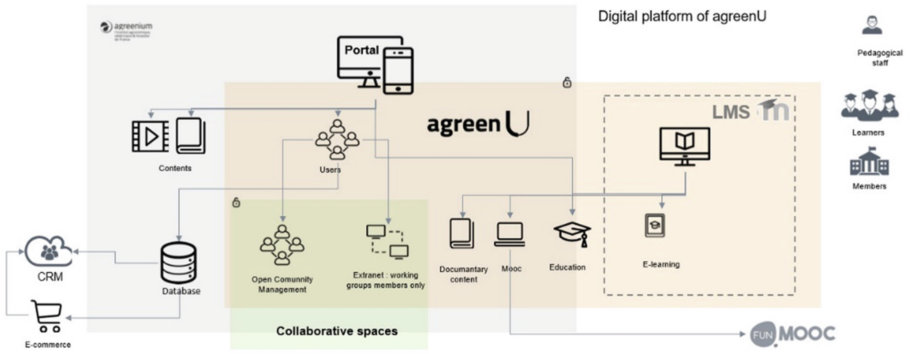


**Fig. 2.** The learning ecosystem of agreen U portal (https://agreenium.fr/u/accueil)

**Acknowledgment.** The authors would like to thank Nexize Company, who contributed to build this project and to gather the data that gave rise to this study.

## References

1. Bejean, S., Monthuvert, B.: Pour une société apprenante - propositions pour une stratégie nationale de l'enseignement supérieur (2015). http://cache.media.enseignementsup-recherche.gouv.fr/file/STRANES/12/2/STRANES_entier_bd_461122.pdf
2. Conseil National du Numérique, Université numérique: du temps des explorateurs à celui de la transformation. Avis (2016). https://cnnumerique.fr/wp-content/uploads/2016/05/CNNum_Avis2016-1_ESR-4.pdf
3. QS World University Rankings by Subject - Agriculture & Forestry, Lists of university ranking (2016). http://www.topuniversities.com/university-rankings/university-subject-rankings/2016/agriculture-forestry
4. Pop, A.: 10 U.S. Universities Offering Top Distance Education (2016). http://www.mastersportal.eu/articles/1307/10-us-universities-offering-top-distance-education.html
5. Sun, P.-C., Tsai, R.J., Finger, G., Chen, Y.-Y., Yeh, D.: What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. Comput. Edu. **50**, 1183–1202 (2008)
6. Durak, G., Ataizi, M.: Learner views about a distance education course. Contemp. Edu. Technol. **7**(1), 85–105 (2016)
7. Bagher, M., Sibbald, A.: Dilemmas facing universities in implementing online learning programmes. In: Proceedings of the 11th International Conference on e-Learning, ICEL 2016, pp. 13–20 (2016)
8. Roman, I.: Development of agronomic education by student-centred learning. In: The 6th International Conference Edu World 2014 "Education Facing Contemporary World Issues", 7–9 November 2014, Procedia - Social and Behavioral Sciences, vol. 180, pp. 441–447 (2015)

# Software Tools for Creating and Presenting Virtual 3D Models

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**Abstract.** The authors of the article define the criteria for a selection of the most suitable software tool for creating and presenting virtual 3D models in educational research. Geomagic Design system is presented as a software that meets the specified selection criteria to create 3D models and the software environment of Adobe Acrobat Reader is a convenient means of their presentation. The experience of the authors from the research application of virtual 3D models in the educational process confirms, that the pupils can work with the mentioned software products without any problems and without any instructions.

**Keywords:** Software tools · Virtual 3D models · Blender · Autodesk Inventor Geomagic Design · Adobe Acrobat Reader

## 1 Introduction

The use of teaching aids and didactic technics in education influences positively the knowledge, skills and habits of pupils gained in the learning process. They contribute to the development of pupils' thinking and are irreplaceable at all stages of the teaching process [1]. The progress in information technologies has a significant impact on today's education methods. By information and communication technologies we understand computation and communication means that support teaching, learning and other educational activities in different ways. These are the technologies that are related to the collection, recording and exchange of information [2].

Education in the virtual environment is currently not a rare phenomenon. The basic prerequisite for success of the used virtual educational method is to create the conditions for executing all or at least part of the lessons with the computer software.

Today's children are in everyday contact with various platforms of information and communication technology. They are under its influence from the youngest age and it becomes a natural environment for them.

The authors in their research work contemplate how to use this phenomenon of modern information era in favour of education. One of the possibilities is the development of


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virtual environments offering not only entertainment, but also education. In a research project aimed at developing the spatial technical imagination of pupils they work with pupils in a virtual environment. They use the virtual 3D models in graphic communication lessons.

The outcome of the project was a design of creative and presentation software tools. The primary aim of the project was to find technically and didactically appropriate programs, in which the virtual 3D models for the needs of the pedagogical experiment could be created and subsequently presented in the educational process. The aim of this article is to show the authors' approach to the design of virtual 3D models for graphic communication teaching.

## 2 Analysis of Software Product Selection

Before performing the evaluation analysis of individual software products it is necessary – on the grounds of objectivity and independence - to define an evaluation methodology that will be used to assess the suitability of software products for research or education purposes. If the result of the analysis shall be a recommendation on the suitability of using the software application in education, then the methodology of the evaluation process must also include consultations with teachers and experts in didactics in relation with their application in education.

In the case of the creating and presenting virtual models, the technical issues of their production are also important. Therefore, the evaluation methodology for the creation and presentation of virtual models must be at the same time developed in close cooperation with the experts who professionally design virtual 3D models.

For the application of virtual models in teaching process it was important to determine the evaluation criteria for the selection of software tools, for their creation and presentation. These were determined as follows:

- price of the software product,
- sufficient technical parameters of the product to perform the simulation of simple geometric bodies,
- low technical difficulty to study and subsequently to create simple geometric bodies,
- availability of trainings and technical support for issues related to 3D modeling,
- full compatibility with presentation software products.

From the school point of view, the primary and decisive factor in assessing software products is their price. Therefore the author's attention has been focused on selecting software products, which are available free. Based on this requirement three software products were evaluated.

## Blender

Blender is an open source[1] software licensed by the GNU GPL for modelling and drawing the 3D computer graphics. This software tool is used, for example, by computer game makers to create the virtual 3D components, from which they will then create the virtual reality of a computer game. Its high technical parameters far exceed the needs of application in teaching or in conventional pedagogical research. The result of this program are very nice and realistic models, but a serious problem for new users is its complicated development environment (Fig. 1). The absence of a local language version may cause certain problems for a user who does not speak one of the world languages, that are connected with studying the program. Another disadvantage for the user of this environment can be the lack of educational and consulting support (institution) in his/her immediate surroundings, which would offer courses, trainings and consulting services for the selected product [3].

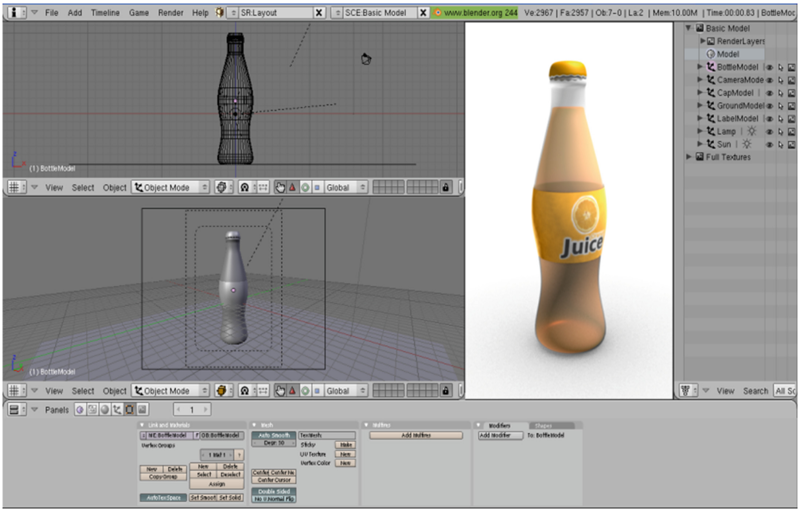


**Fig. 1.** Development environment of Blender [4]

## Autodesk Inventor

It is Autodesk's software product, which is used to design virtual 3D models of mechanical systems and to create the technical documentation. Inventor can simulate the

[1] In general, open source is any information available to the public under the condition that the possibility of its free distribution remains preserved. In this case, it is not important to talk about licence fees, open source means freedom of access. Open source is the philosophy of an open source movement founded by Eric Raymond. Specifically, open source means open-source software, which was the original meaning. It was later generalized (generally, open content is also used). Open source software must have an available source code; end users must have the right to use it free, modify and distribute the software, as well as the right to pack and sell the product. Software with the source code released as a public domain, even under the GNU General Public License (GPL), complies with these conditions.

movements and mechanical features of functional units (Fig. 2). Although this product is very expensive, the company Autodesk supports the teachers community by providing a free downloadable full versions of their products for the needs of teachers. The special licence keys to all company software products are distributed to every registered teacher (through a work email address). As a disadvantage we consider the unavailability of the product's licence for presentation purposes. Free licences for teachers refer only to the use of the software for the pedagogue's self-study. The product therefore can not be used in teaching process. There are some free downloadable presentation tools, but they require IT engineers to intervene during their installation. All other Autodesk products such as: AutoCAD, 3DS MAX, Maya, which would be ideal tools for creating and presenting virtual 3D models, are characterized by the same disadvantage [5].

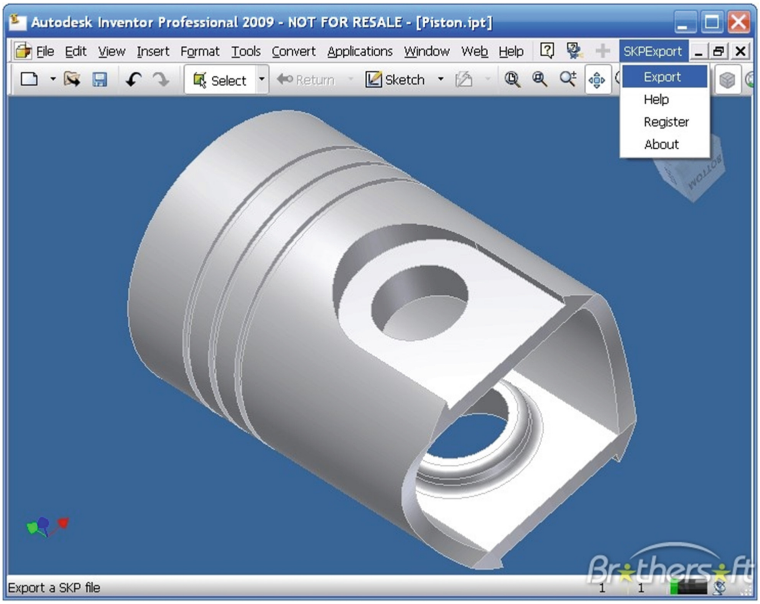


**Fig. 2.** Development environment of Inventor [6]

### Geomagic Design

Geomagic Design is a commercial product of Geomagic 3D, which develops software tools for creating the virtual 3D models with the subsequent export of control codes for CNC machines (CAM system). In the case of the 3D model design itself, the company makes the program available for 30-day trial period. During this time it is possible to create the required models without purchasing the product. A cost-effective licence can be purchased for the school needs (study, teaching or presentation). In the case of Slovak Republic, the slovak localization of the product allows the user to ask questions about the development of 3D models to experts in this field. Another advantage for users is the possibility to participate in a free 3D modeling course of Geomagic Design program. By completing the course, the development environment of this product appears to be very clear, logically organized and easily manageable even for the very beginners. The decisive factor for the selection of this product is its ability to export a virtual 3D model into an interactive 3D pdf format, which can be then presented with a commonly available Acrobat Reader browser.

After evaluation of the advantages and disadvantages of selected software products and following the discussions with experts on creating and presenting 3D virtual models we came to the conclusion that the Geomagic Design will be the most convenient tool to create virtual models aimed for teaching. An example of the simulation in the Geomagic Design development environment is shown in Fig. 3.

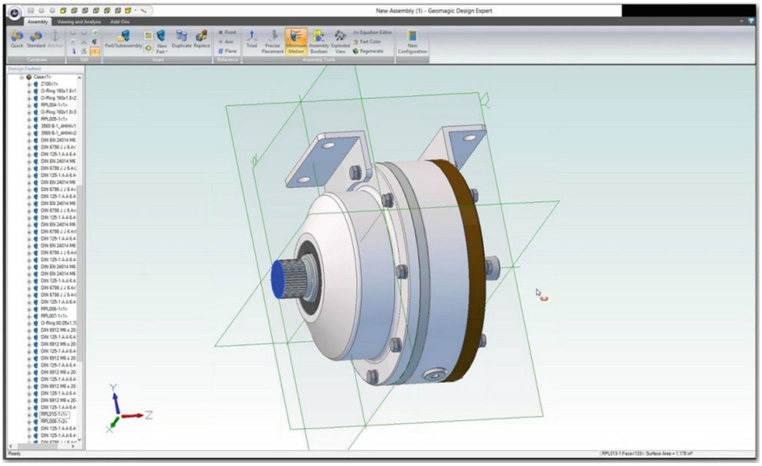


**Fig. 3.** Development environment of Geomagic Design [7]

We mentioned that, to be able to select an appropriate software environment for creating the virtual 3D models applicable in teaching process, it is necessary to perform an evaluation of selected programs also in terms of the presentation of 3D models. After discussion in a wider group of teachers, didacticians, programmers and technicians the evaluation criteria of software tools designed for presentation of the virtual 3D models were proposed as follows:

– availability, price and technical compatibility of the presentation software with the means of information and communication technology in primary schools where it is planned to teach or to make a pedagogical research,
– compatibility of the presentation tool with the software in which the virtual 3D models will be created,
– simple and intuitive installation of the product and its supporting tools which can be also done by laics in the field of information technology,
– simple and intuitive control (the most similar to computer games) of a virtual reality environment in which the 3D models will be presented,
– clarity of the control elements,
– smootheness of responses in the virtual environment to user suggestions,

– opportunity to simulate the models in different modes (wire model, full model, wall transparency, etc.).

In most cases, in practice the software itself designed for creating the 3D virtual models is used as a presentation tool. In the case of the research program of the graphic communication course in schools with the support of virtual 3D models realized by authors, it was not possible to use this most commonly used approach because the development tool environment was very complicated for the moderator or the software had licence limitations for projection and presentation.

After evaluating all factors included in the applied research project and after discussion with the teachers of elementary schools, where the research was going to be realized we have come to the conclusion that the most advantageous presentation tool, whether in terms of didactics or technical possibilities, appears to be the program Adobe Acrobat Reader which is a common and freely downloadable part of almost every computer. Adobe Acrobat Reader can show, except of the standard pdf documents, also interactive and virtual 3D models that can be created and exported by Geomagic Design.

## 3 Presentation Virtual 3D Environment of Adobe Acrobat Reader

Adobe Acrobat Reader (AAR) is a software product belonging to the group of application and web supporting programs, which are developed by the company Adobe Systems, for viewing, creating, manipulating and printing the Portable Document Format (PDF) files. Currently, the available AAR versions have implanted libraries also for viewing 3D models in PDF format.

An indisputable advantage of this program is its easy (available at any free software server) and free access. The AAR program is currently installed in almost every computer.

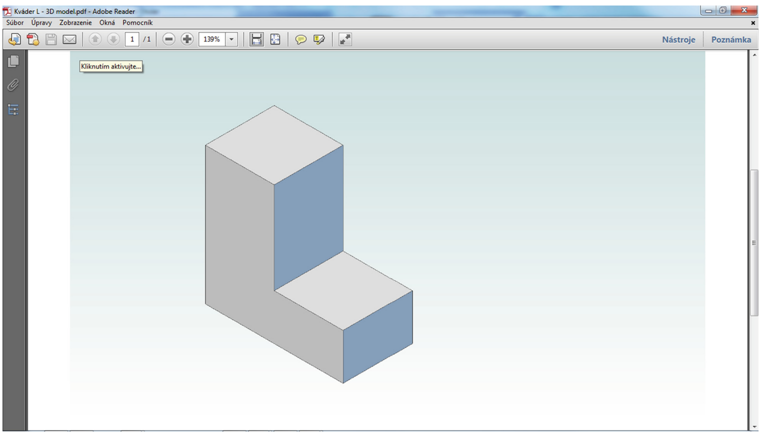


**Fig. 4.** An image of the 3D model created by AAR immediately after opening the PDF file

To display a virtual 3D model in AAR it is necessary to create this model in one of the CAD/CAM programs (in our case in Geomagic Design) and consequently to export it into the PDF file.

After opening such file in AAR, the 3D model will appear in settings that were used to export it into the PDF file (Fig. 4). In this representation it is not possible to change views, rotate or move the 3D model and so on.

By clicking the left mouse button on the shown 3D model, the virtual interactive 3D environment will be activated (Fig. 5), where it is possible to change the parameters of images of the 3D model by using the toolbar panel (Fig. 6) or by mouse. It is possible to set the basic views of the virtual environment by mouse. For example, by pressing and holding the left mouse button and moving the mouse we can rotate the displayed 3D model in the direction of the mouse movement. By pressing and holding both the right and left mouse buttons at the same time the object can be moved in the virtual space. By rotating the centre wheel of the mouse it is possible to zoom in or zoom out the object from the imagined position of the user in a virtual 3D environment. It is important to point out that such a system of the virtual 3D environment controlled by mouse is the same as a control of 3D computer games [8].

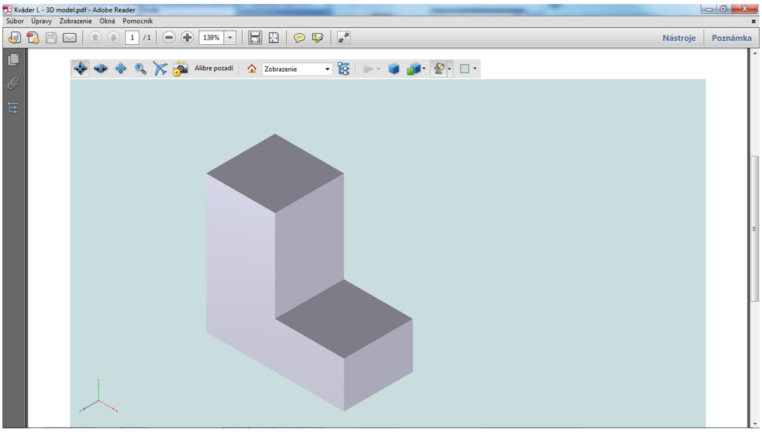


**Fig. 5.** Activated virtual 3D environment

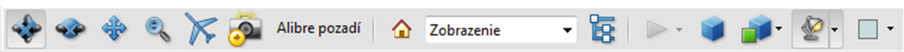


**Fig. 6.** Complete toolbar of the virtual 3D environment

An important part of the displayed virtual 3D environment is the already mentioned toolbar (Fig. 6). With these tools it is possible to change the parameters of the virtual 3D environment as well as the display modes of virtual models.

The “Alibre background” tool lets you choose the background color of the displayed virtual 3D space. There is a wide variety of colors available.

## 4 Design and Creation of Virtual 3D Models

The authors of the article proposed virtual 3D models for graphic communication teaching.

Their research has confirmed that the didactic tools presented by virtual reality systems are able to substitute the didactic aids presented by the real subjects sufficiently. It has also been confirmed that pupils can easily use and control the environment of the virtual reality presentation system without any prior instructions. The authors of the research have confirmed that the current generation of children perceives the virtual computer environment as a normal part of their life in which they can intuitively orientate themselves without any previous instructions and only on the basis of their computer skills [9].

An analysis of the suitability of using the software tools for the purpose of the research project has shown that from available software tools the Geomagic Design is the most suitable program for creating virtual 3D models and Adobe Acrobat Reader (AAR) is the most suitable presentation tool.

The use of AAR software as a virtual reality presentation tool appears to be a unique and technically elegant solution. Many AAR users do not even know that the software privately used for viewing pdf documents, can also work as a virtual reality presentation tool.

The technological process of creating virtual bodies in Geomagic Design is strongly influenced by the methods of machining the materials for which this CAM system was created. In the theory of the material machining the basic operation processes are turning and milling which are supplemented in this software system with supporting functions such as 2D sketch, body pulling into the space, etc. Geomagic Design fully supports parametric modeling, interactive dimensioning or defining the geometric bonds during the creation of 3D models (Fig. 6). Some more complicated models requiring logical operations of virtual body bonding need to be developed in cooperation with specialists from practice (e.g. some shapes of cut surfaces). The indisputable advantage of Geomagic Design is the creation of 3D body technical documentation through an automatic drawing system that, based on the defined model and the set parameters of the drawing, will create the complete technical documentation without the need of the user's intervention.

The created virtual 3D models used by the authors in the research project are shown in Fig. 7.

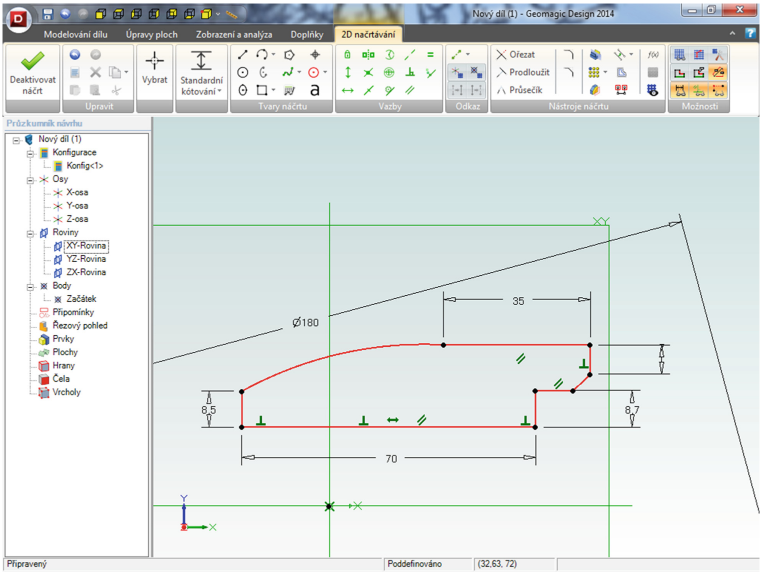


**Fig. 7.** Parametric drawing and modeling in Geomagic Design

The detailed results of the research are presented in the publication by P. Kuna, S. Kunová, T. Kozík: "Developing the technical imagination of elementary school pupils with the support of virtual 3D models" [9] (Fig. 8).

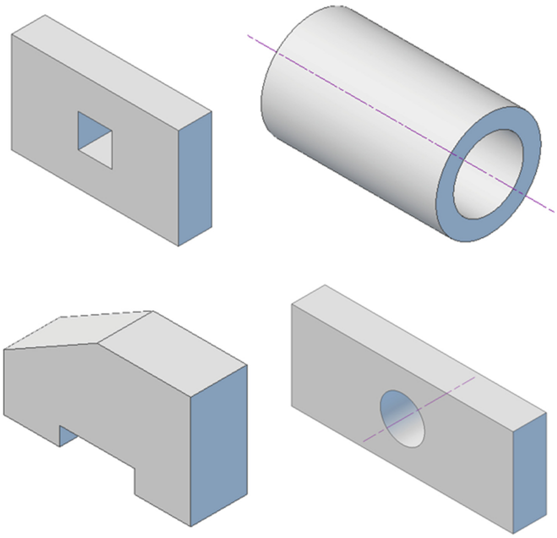

**Fig. 8.** Shapes of virtual 3D models prepared for research purposes

## 5 Conclusion

Based on the experience gained with the creation of virtual 3D models and the experience gained during the application of virtual 3D models in this pedagogical experiment the GeomagicDesign meets the best the set selection criteria and Adobe Acrobat Reader software is the best for presentation of the models.

Adobe Acrobat Reader represents an elegant means of presentation of virtual 3D models in the form of an established PDF document viewer. It is a cheap and widespread software environment, which can be obtained without any problem by every school. This presentation environment is fully compatible with computer game systems. Pupils are really familiar with this type of systems. The experience of the authors from the research application showed that the pupils are able to work with it without any problems and without any instructions.

## References

1. Dubovská, R., Lajčin, D.: Didaktika odborných predmetov. www9.siov.sk/ext_dok-dop/. Accessed 22 Dec 2015
2. Martinčeková, I., Tóblová, E.: Didaktika odborného výcviku. Bratislava: Metodicko-pedagogické centrum, 2013, 67 s (2013). ISBN 978-80-8052-465-4
3. Blender: Blender Reference Manual. https://docs.blender.org/manual/en/dev/. Accessed 16 May 2017
4. Freeware Blender for Linux, Blender. http://freeanalogs.com/Linux/Blender. Accessed 15 May 2017
5. Shahan, J.: Autodesk Inventor Tutorials 2014. http://home.engineering.iastate.edu/~jcshahan/InventorTutorials_jcs-WebLinks.pdf. Accessed 20 Mar 2016
6. BrotherSoft: SKP Export for Inventor 1.0. http://www.brothersoft.com/skp-export-for-inventor-216661.html. Accessed 15 May 2017
7. B3-D Mcad Consulting, Geomagic Design. http://www.b3-d.com/design.html. Accessed 15 May 2017
8. Adobe: Displaying 3D models in PDFs. https://helpx.adobe.com/acrobat/using/displaying-3d-models-pdfs.html. Accessed 15 May 2017
9. Kuna, P., Kozík, T., Kunová, S.: Developing the technical imagination of elementary school pupils with the support of virtual 3D models. JTIE – J. Technol. Inf. Edu. (2017, in press). ISSN 1803-537X

# Teaching Design Project in Introductory Engineering Course Using 3D Modeling and Immersive Virtual Reality

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**Abstract.** This paper presents a new approach for delivering the project component in introductory engineering course. The approach is based on using 3D modeling software to create the prototype of the product. Furthermore, immersive VR display were utilized to enable the students to explore and inspect their design in different stages and discover the problems in the design. The approach enabled the students to get perception of their design and interact with the model from different angle and navigate around which gave them closer look at the design that usually impossible using the traditional 2D display. The results showed that the VR approach increased the attainment of the students in the project.

**Keywords:** Project-based learning · Immersive education · Virtual reality

## 1 Introduction

Preparing students to cope with emerging and futuristic technological innovations learners need to be taught using well engineered interactive training environments and methods [1] that deliver results close to hands on training, from the first moment they admit into the university. The bright potential of tomorrow is linked to application of engineering and IT concepts [2]. Virtual Reality (VR) provides real time visualization and interaction within a virtual world that closely resembles a real world [3, 4]. Moreover, with the recent advancement in virtual reality technology VR systems became affordable and relatively cheap with new consumer devices and game consoles adopted at homes is to be considered a new shift in the gaming industry. VR is able to provide a constructivist learning because it enables the learners to be actively involved in highly interactive environment [5]. Constructivist learning model, which was first proposed by Reigeluth [6], is a philosophy of learning that believes knowledge is constructed by learner through experience and activity [6, 7]. Many studies pointed out how VR technology that equipped with various technical capabilities can support constructivist learning principles [8, 9].

The main learning objective of providing design project in first year engineering fundamentals course is to enable the students to apply and practice the engineering design process that has been covered in theory, in addition to teach the student to think


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and consider practical issues and constrains while creating solution for any project. The traditional project style in helping students to achieve these objectives suffers from many problems. The project is either too ambitious therefore the students are not able to actually implements or test their assumptions or it is very simple where they can apply only some design and engineering concepts that still close to K-12 level, as a result the students will not be able to apply all the design steps. The proposed idea in this paper is providing a new learning style to enable the students to design, create, and evaluate their prototypes with the help of virtual reality technology. The design and development of the product is achieved using 3D modeling tools (virtual prototyping). Moreover, virtual reality immersive CAVE display were utilized to enable the students to check and evaluate their design in interactive and intuitive environment with high sense of presence, realism, and immersiveness. Using this new approach is expected to increase the students' motivation and their attainment in project completion.

Interactive virtual environment and simulation is a mythology for teaching that allow learners to practice and test their knowledge in circumstances that are similar to real world. In the proposed approach the students designed and created the virtual world themselves. This expected to increase the information retention and add new dimensions to the learning process such as creativity and motivation.

The research in [10] demonstrated the feasibility of applying VR as a tool for conveying engineering concepts to first year engineering students. They concluded that the teaching tool contribute largely to the student retention of engineering concepts although no results were published. They also used a non-immersive VR 3D design platform as a teaching tool. In this research we use a fully immersive virtual environment with large scale display that provides high sense of presence and interactivity. Lee et al. and her colleagues [11] studied the potential of desktop VR technology to support and enhance learning and developed a theoretical model and a board framework to explore the determinants of learning effectiveness in a desktop VR-based environment. The result show that satisfaction and perceived learning effectiveness influenced greatly the learning outcome. Meanwhile performance was less influenced due to the fact that performance achievements is influenced by a myriad of other factors. Considering the previous result, the proposed system is expected to score high in the measurement criteria that related to presence, motivation, control and active learning, and reflective thinking which will lead to higher influence on the learning outcomes. The work in [12] presented teaching methodology for a practical course in virtual reality for engineering students. No solid evaluation of the impact of using VR on the overall performance or outcome was presented, however it was noted that the students' motivation increased.

The paper presents a new approach for conducting engineering design project using 3D modeling as a prototyping technique and immersive Virtual Reality (VR) platform to inspect the prototype and evaluate the design. It also presents an assessment of the effectiveness of this approach on the performance of the students who are taught using this teaching approach compared with traditional approach.

## 2 Infrastructure

The course project demonstration was hosted in the Virtual Reality Lab in the College of Engineering at Qatar University. The Lab was established in 2015 with the state-of-art equipment in virtual reality hardware and software. The lab is equipped with high fidelity virtual reality environment and a distributed stereoscopic visualization in a four-sided C.A.V.E. (Cave Automatic Virtual Environment) display (3walls + floor). The display is supported with high-precision tracking using PPT (Precision Position Tracking) with high speed optical sensors. This enables interaction ability using tracked wands. The whole system provides large-scale screens with stereoscopic vision and high degree of interactivity, see Fig. 1.

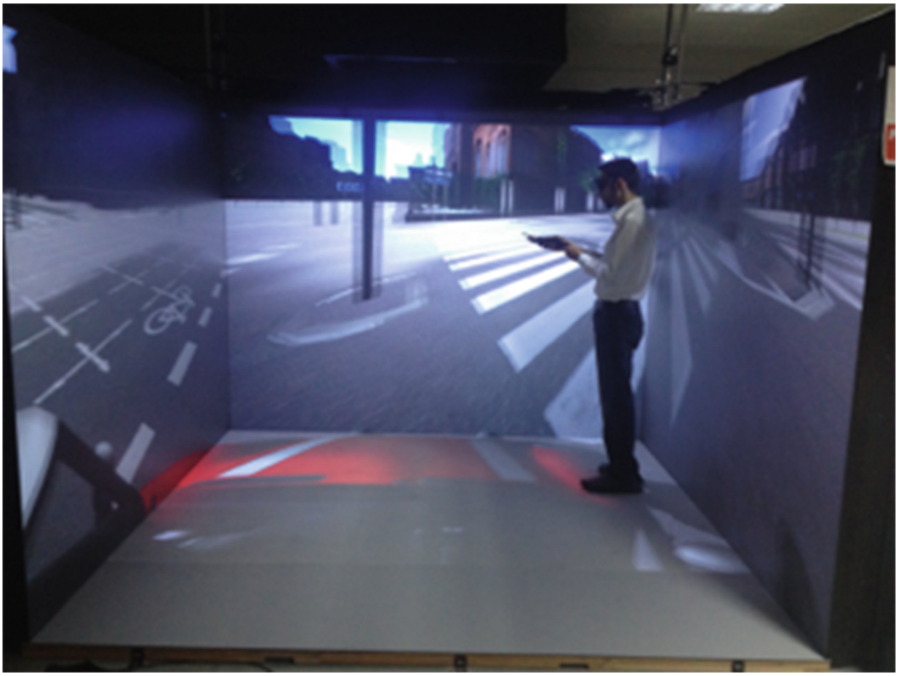


**Fig. 1.** CAVE system at Qatar University

## 3 Methodology

The approach is based on comparison between the traditional approach of delivering design project and the new proposed VR-based approach in terms of performance. The two approaches were applied on different sections during different semesters. The traditional approach is based on giving the students several project ideas and ask them to select and develop final prototype. Since the main objective of the design project is to enable the student to apply all the engineering design steps from idea generation to testing and evaluation, the ideas had to be simple and selected carefully to be applicable and easy to implement so that the student would be able to create the final prototype and test it. This obviously limited the scope and level of difficulty of the projects and also constrained the creativity of the students to generate different approaches and ideas to address the objectives of the project.

In the VR-based approach the students were given a real-life project idea. They were asked to apply all the engineering design steps, therefore, each team have to create three designs and select the best design based on the evaluation matrix. After selecting the best design, they have to create a prototype. Creating sophisticated and detailed prototype is difficult to achieve using the traditional tools. In the proposed approach we utilized the 3D modelling technique which is widely used in many industries to save time and money during the design stage. Therefore, the student was asked to use 3D modelling software to develop their prototypes and encouraged to add all the fine details that usually needed in real-life solution. In our case, they were taught how to use SketchUp Software which was easy and sufficient to create detailed design. Figure 2 shows how details were added, e.g. assistance handles were added in specific spots, Fire extinguisher, sockets and coffee maker. Figure 5 as well shows how students cared about all the details that usually exist in real-life kitchen.


**Fig. 2.** The designs considered all the necessary details to produce final real model. For example, the handle to assist the person in wheelchair, the fire extinguisher for safety, the sockets, coffee maker, and other details.

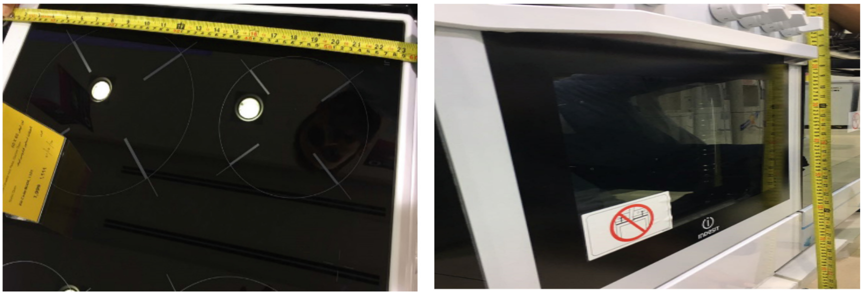
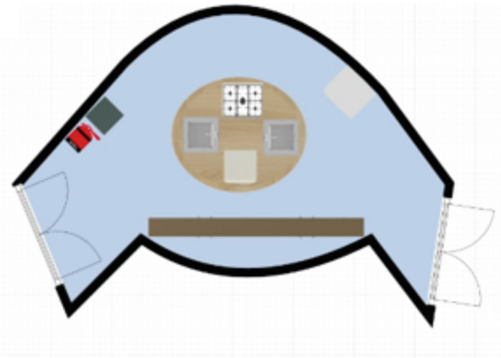


**Fig. 3.** Students went to the market to get real price and dimensions of the components. The left photo shows electrical stove, and the right photo is a microwave.

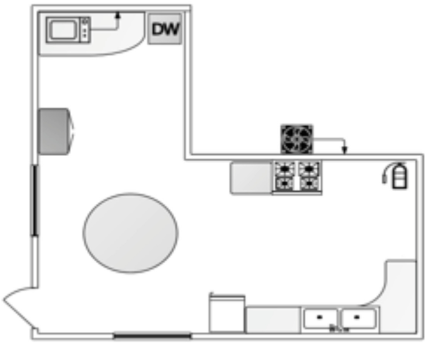
The students had to deliver the 3D model in a certain format to be able to view it on CAVE display. This was simple enough as the software provides the capabilities to export to different 3D formats. Also, they were taught how to align the model view to the CAVE display so that the viewer stands in the middle of the design. The students enjoyed many small details on how to deal with 3D graphics and were impressed to see their work on the display and all achieved by themselves. The students were first asked to brainstorm to find at least three different solutions and then start analyzing each solution based on the criterial of success and constrains that the students identified. Figure 4 shows three different solutions presented from which the circular design was selected based on the evaluation matrix for the three kitchen designs.

After selecting the final design, the students started developing their prototype using 3D modeling software. To allow students to check their design and get feedback and not leave it to the last day of final submission, two visits to Virtual Reality Lab were arranged for the students, one to check their initial design and another one to present their final design. In the first visit, each group were able to test their design, navigate, and interact with it. Furthermore, the demonstration was in front of all class which also provided good chance for other students to see different ideas and also to give their comments and feedback. The whole experience was engaging to other student as they were also able to wear 3D glasses and experience with the presenter the design. This increased the involvement of the whole class and provided a great atmosphere for constructive discussion and comments. The CAVE display provided immersive experience with almost real scale size so the students were able to inspect their design and were able to find many problems that usually hard to detect in 2D display. This step was very essential and very useful for the students and enabled them to apply evaluation and enhancement steps on their design. The students addressed these problems in their second visit where they demonstrated the final design. Figure 5 shows the final design for the design kitchen in Fig. 4(a).

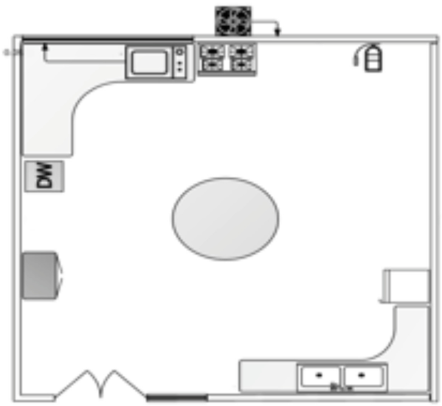
One additional important details considered in the design of every project is that the students were asked to use real scaling in their design as this will be reflected in the CAVE display. This forced them to use real dimensions for every object used in the design. To achieve this objective, they had to look in the market for real components and get their dimensions to be able to add them to their design. Figure 3 shows how



(a) The Circular design of the kitchen.

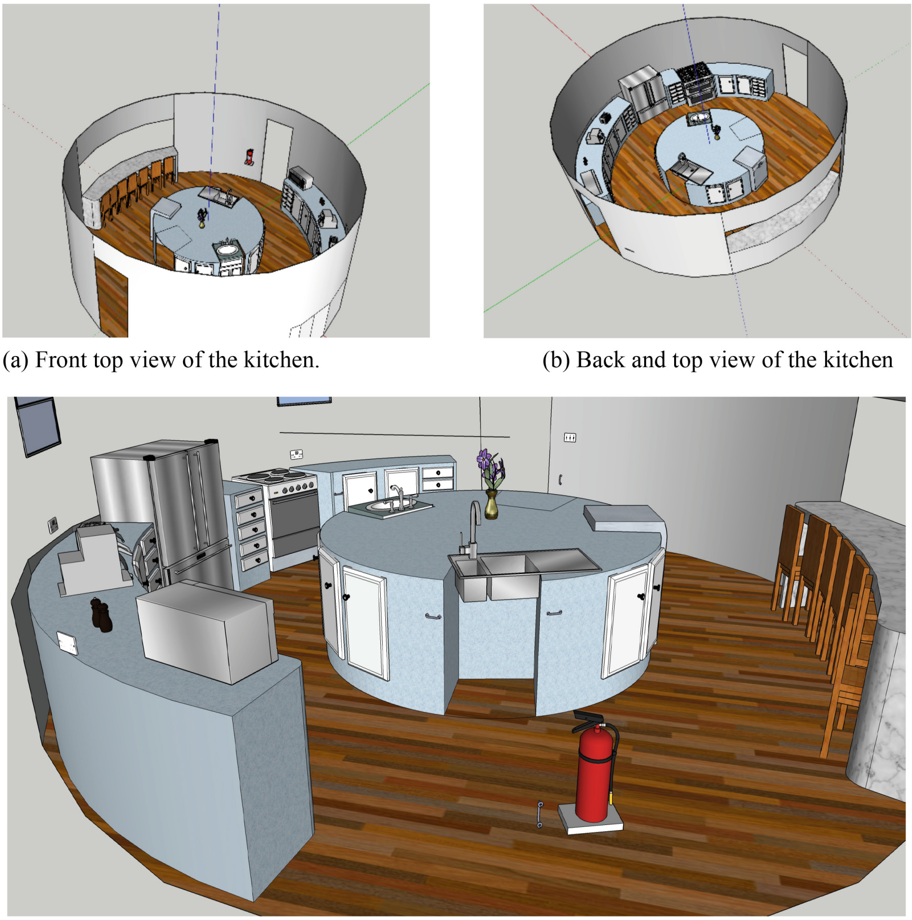



(b) The L-shape design of the kitchen.




(c) The square design of the kitchen

**Fig. 4.** Three designs represent three different creative design ideas for the kitchen as presented on the final report as an example for one team project.



(a) Front top view of the kitchen.

(b) Back and top view of the kitchen

**Fig. 5.** The 3D model of the kitchen with all the details. The model is an implementation of the design presented in Fig. 2(a).

students went to the market and selected the components for their price to meet the budget constraint and also measured them before adding to the design.

## 4 Experiments and Result

The students were asked to design a kitchen for wheelchair people with specific constraints on budget, room size, and materials. Safety aspect was crucial for the success of the project in addition mass production. The number of students for the traditional section were 24 students, and they were 31 students in the section that VR approach was applied. Questionnaire was used to explore factors about the project difficulty and how it motivates the student to work as a team. As a quantitative measure, the grade of the students at each section was used to compare between the two approaches. We used the project grade to evaluate the effect of each approach on the student performance in conducting their project specifically.

Two sessions were arranged for the students to visit the lab and check their design in the CAVE display. In the first visit they were asked to inspect their model and identify the problems by imagine themselves using the kitchen. The interactive high fidelity display enabled the students to discover many problems in the design that was impossible to see in normal desktop display as expressed by the students. Issues like the positions of the electrical sockets, the difficulty in reaching out the end of the stove, the lack of safety, difficulty in cleaning in between the cabinets, etc. The instructor was also able to give a useful feedback about the design and gives hints about how to improve the design. The students were asked to consider these issues and think how to modify their design to address them. This considered as first evaluation of the product and enabled the students to experiment the nature of iterative design process. They were given a second chance to demonstrate how they addressed the design problems that discovered during the first visit and how they improved the final design as well. The final design during the second demonstration in virtual reality lab of the same kitchen presented in Fig. 5 can be seen in Fig. 6.

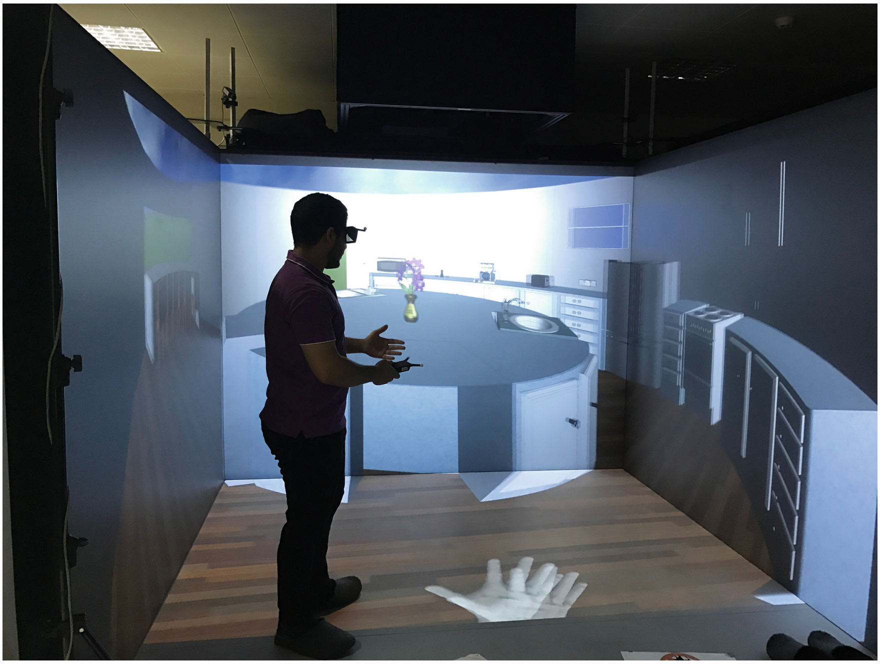


**Fig. 6.** The student is demonstrating the final design of the kitchen in CAVE. The design is the final design for the same kitchen presented in Fig. 4.

The analyses of the project grade for the two sections showed that the average final grade value was 84.54 for the students used the VR approach compared to 77.04 for the students who used the traditional approach as can be seen in Fig. 7.

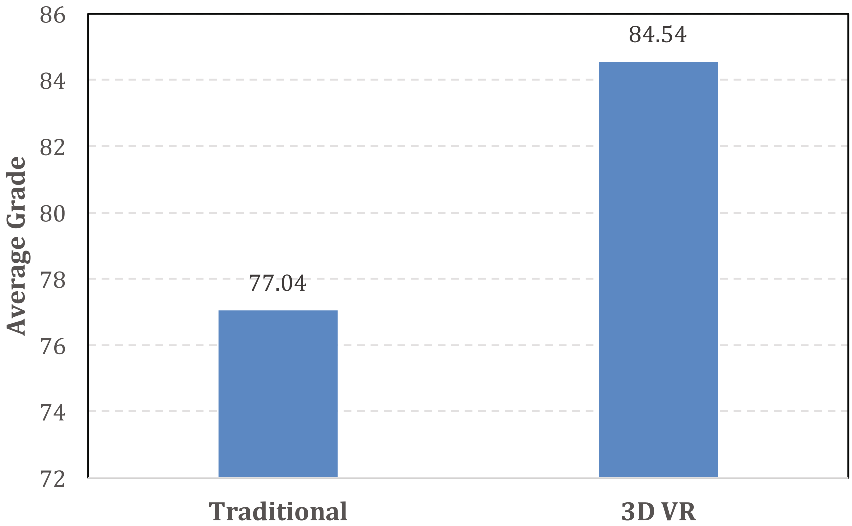



**Fig. 7.** The final grade for project grade for VR approach and traditional approach.

Further analysis to the final prototypes showed that the students were able to add fine details on the design and addressed all the safety and accessibility issues as adding these details is much easier than real mockups or any other tools for prototyping. Another result that can be concluded from the questionnaire is that the students were very excited about using this approach and many thought that this considered an important skill for their carrier as engineers and would be very useful in the future. This also might be the explanation on why they were also very motivated as well.

## 5 Conclusion

This research explored the delivery of introductory engineering course to teach engineering design process and skills using a project-based learning methodology to implement a virtual prototype in fully immersive VR environment. An assessment of the approach is provided based on the student performance. The use of 3D software and VR as a new teaching-learning environment can empower the engineering students with new tools to design, create, and evaluate new ideas. The new advancement in VR technology increased the quality of visualization and make it affordable. This makes VR a viable alternative to traditional teaching method. Furthermore, VR can be a powerful tool for testing and evaluating new products and ideas. The result of this research also demonstrated how the students effectively interacted with environment and were able to visualize their design problems. Hence, it is important to emphasize that VR is not merely for visualization purposes, instead it offers an improved method of interaction and visualization that can be applied in real engineering problems. This can be applied to different engineering disciplines including mechanical, electrical, chemical, and architectural.

## References


1. Abulrub, A.G., Attridge, A., Williams, M.A.: Virtual reality in engineering education: the future of creative learning. Int. J. Emerg. Technol. Learn. **6**, 4–11 (2011). https://doi.org/10.3991/ijet.v6i4.1766
2. Jette, S.: The Third industrial revolution– how lateral power is transforming energy, the economy, and the world. World Futur. Rev. (World Futur. Soc.) **4**, 199–202 (2012). ISBN 978-0230341975
3. Chuah, K.M., Chen, C.J., Teh, C.S.: Incorporating Kansei engineering in instructional design: designing virtual reality based learning environments from a novel perspective. Themes Sci. Technol. Educ. **1**, 37–48 (2008)
4. Ai-Lim Lee, E., Wong, K.W.: A review of using virtual reality for learning. Trans. Edutainment **1**, 231–241 (2008)
5. Kim, J.-H., Park, S.-T., Lee, H., Yuk, K.-C.: Virtual reality simulations in physics education. Interact Multimed. Electron J. Comput.-Enhanc. Learn. **3**, 1–7 (2001)
6. Reigeluth, C.: What is instructional-design theory and how is it changing? Instr. Theor. Model New Paradig. Instr. Theory **2**, 5–29 (1999). https://doi.org/10.1007/s13398-014-0173-7.2
7. Martens, R., Bastiaens, T., Kirschner, P.A.: New learning design in distance education: the impact on student perception and motivation. Distance Educ. **28**, 81–93 (2007), https://doi.org/10.1080/01587910701305327
8. Huang, H.M., Rauch, U., Liaw, S.S.: Investigating learners' attitudes toward virtual reality learning environments: based on a constructivist approach. Comput. Educ. **55**, 1171–1182 (2010). https://doi.org/10.1016/j.compedu.2010.05.014
9. Amarin, N.Z., Ghishan, R.I.: Learning with technology from a constructivist point of view. Int. J. Business Humanit. Technol. **3**, 52–57 (2013)
10. Laseinde, O.T., Adejuyigbe, S.B., Mpofu, K., Campbell, H.M.: Educating tomorrows engineers: reinforcing engineering concepts through Virtual Reality (VR) teaching aid. In: IEEE International Conference Industrial Engineering and Engineering Management (IEEM), pp. 1485–1489, January 2016, https://doi.org/10.1109/ieem.2015.7385894
11. Ai-Lim Lee, E., Wong, K.W., Fung, C.C.: How does desktop virtual reality enhance learning outcomes? a structural equation modeling approach. Comput. Educ. **55**, 1424–1442 (2010). https://doi.org/10.1016/j.compedu.2010.06.006
12. Häfner, P., Häfner, V., Ovtcharova, J.: Teaching methodology for virtual reality practical course in engineering education. Procedia Comput. Sci. **25**, 251–260 (2013). https://doi.org/10.1016/j.procs.2013.11.031

# Low Cost Industrial Interface Design and Graphical Programming for Arduino

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**Abstract.** This paper consists of the development and design of a low cost programmable logic controller device. For this purpose, we designed an electronic circuit to make the inputs and outputs of the Arduino platform compatible to industrial standards of electrical signals. In addition, the programming of the electronic device uses a graphical diagram interface to facilitate the interaction with the user. In order to design this embedded system, the choice of accessible, low-cost and open-source components was of great relevance, as is the case with ladder programming software. The fact of being open-source enhances collaboration and adaptation for specific applications. This project applied as a tool for teaching in engineering has generated promising results.

**Keywords:** Embedded systems · Programmable logic controller · Arduino

## 1 Introduction

Nowadays, industrial automation is essential to meet the requirements of the competitive and demanding market in the scenario of globalization. Thus, companies had to undergo an adaptation process to increase productivity and competitiveness [1]. As a consequence of this transformation, a new professional engineer profile, compatible with the labor market, emerged. From then on, the academia had to adapt itself by proposing changes in engineering education in order to prepare more qualified professionals [2]. A Project-Based Learning strategy can be successfully applied in this context in which students develop their skills effectively [3–5].

All this process was followed closely by the development of technology, which also began to be applied as a tool in the teaching-learning process. Developing that motivation and interest in students can help them enhance academic performance and content assimilation. The students who apply theory to practice can become more involved with the course and improve their skills in solving real problems [6].

The availability of low cost and easy to replicate devices in the academic community contributes to the dissemination of knowledge [7]. In addition, it is an open-source hardware and software project. The device can assist the student in the most diverse applications. The electronic device proposed in this paper has a very low production


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cost when compared to a similar commercial product, the PLC (Programmable Logic Controller), often applied in industrial automation [8]. For this purpose, we designed an industrial interface for the Arduino board.

## 2 Specifications and Software

For reasons already highlighted in this paper, and due to the practicality and the large amount of information available, we chose the Arduino Uno R3, with Atmel ATMEGA328 microcontroller. Arduino is a development platform of great applicability that has been widely used in academia and in the scientific community [6].

The program was developed using the Ladder Maker environment, version 110a. It is free and open-source software that allows us to program an Arduino platform using ladder - a graphical language commonly used in industrial PLCs. This programming language is made up by contacts, as well as counters, timers and mathematical operations. The computer loads de code through a USB cable. The software converts the ladder logic to the hexadecimal code that is written to the ATMEGA controller. The Fig. 1 shows the graphical interface of the program.

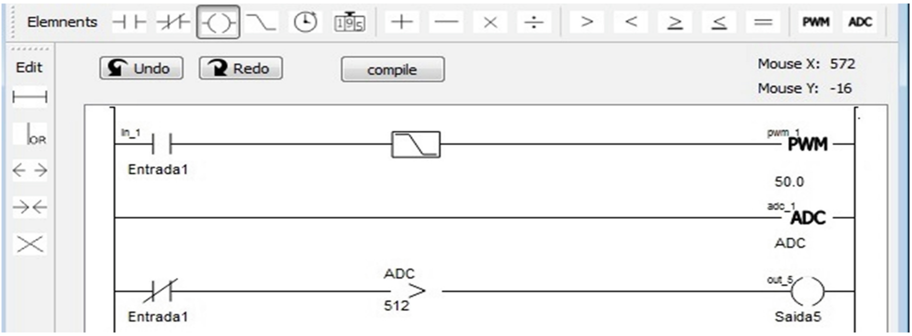


**Fig. 1.** Programming interface

The current and voltage analog ports can be in the 4 to 20 mA or 0 to 20 mA and in the 0 to 10 V standards, respectively. At the inputs, the distinction between them is made by making a correct association between the desired value and the value encoded by the analog-to-digital converter (ADC). In the PWM outputs, the distinction is made through the code. To suit them to the 4 to 20 mA standard, a simple mathematical adjustment is required in version 110a of the Ladder Maker software.

The digital inputs and outputs follow the voltage standard 0 for low level and 10 V for high level. In version 110a, the internal pull-up resistor was activated for the inputs, resulting in activation by low level. So, we changed the inverted activation logic. This could be done via code by writing the value zero on the *PINC4*, *PINC5*, *PIND2*, *PIND3*, *PIND4* registers on the Arduino controller. These registers are associated with the pins that have been implemented as digital inputs. In addition, it was necessary to invert the processing logic of normally closed and open contacts.

## 3 Interface Design

From the device specifications, we defined the electric circuits that met the requirements of the system. The connection diagram in Fig. 2 shows where the inputs, outputs, and power circuits were connected to the Arduino. The details of each circuit will be presented shortly thereafter.

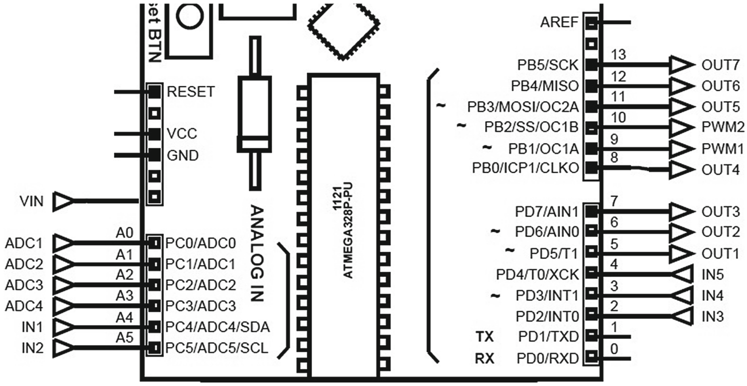


**Fig. 2.** Arduino connection diagram

In the digital inputs, we reduced the voltage in half (from 10 V to 5 V) to be compatible with the high level of the Arduino. For this, a voltage divider with two high impedance resistors was implemented to request less current from the device that supplies the signal.

After disabling the pull-up resistors of the Arduino inputs, the signal fluctuation problem might occur. This happens when the input state is undefined, because it is neither high nor low. The circuit proposed in Fig. 3 solved the fluctuation problem, since one of the resistors of the voltage divider functions as a pull-down resistor, causing the input to be internally grounded, assuming, therefore, zero even when nothing is connected.

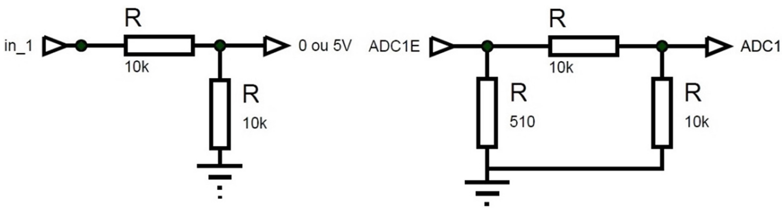


**Fig. 3.** Digital inputs/Analog inputs

Analog inputs as well as digital inputs have a voltage divider. The current pattern can be converted to voltage, 0 to 10 V, and then to 0 to 5 V to be processed by the Arduino. We decided to dimension a resistor to make the voltage equivalence from the analog current signal, and to couple the current circuit to the voltage circuit to make the electronic design more compact, as shown in Fig. 3.

The analog outputs were implemented via the PWM digital outputs. Each Arduino PWM signal is initially inserted into a RC series circuit, which functions as a first order low pass filter, as proposed by [9]. Then, it passes through a voltage buffer - an operational amplifier of unit gain - in order to isolate circuits in terms of impedance. Since the Arduino provides voltage ranging from 0 to 5 V and the adopted standard was 0 to 10 V, an operational amplifier was designed in the non-inverting configuration with gain 2. The resulting circuit is shown in Fig. 4.

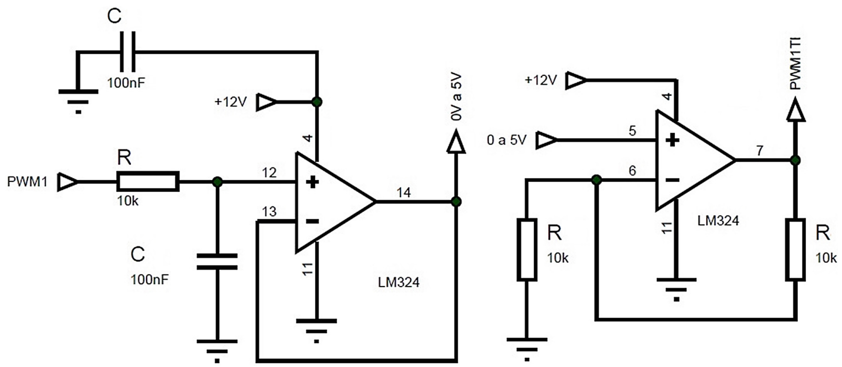


**Fig. 4.** PWM output interface

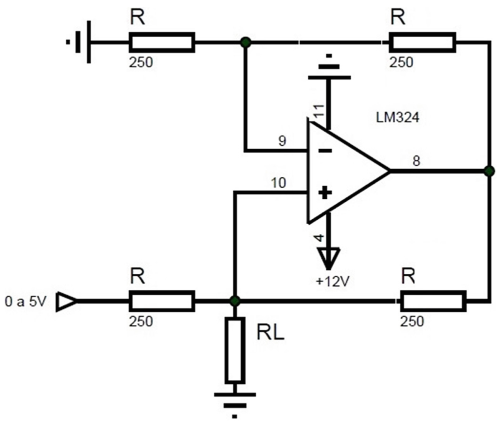


**Fig. 5.** Analog output current source

In the current outputs, a voltage/current converter known as a Howland current source was used [10]. This source generates bidirectional current in the load and is directly proportional to the input voltage. In addition, this circuit has as its main characteristic the fact that the generated current does not depend on the load that it feeds.

This property becomes very useful, since devices that read this type of signal usually have low input impedance. The circuit is shown in Fig. 5.

The digital outputs were adjusted to the 0 to 10 V standard by means of a non-inverting operational amplifier with gain 2, as the circuit on the right in Fig. 4.

The supply circuit comprises a 12 V DC voltage source for the operational amplifiers. From the source, a 12 V to 9 V voltage regulator was used to power the Arduino in the Vin pin. In this way, it can work even without connection to the computer. To protect the circuit, a diode was added to the power supply and, to ensure stability, a decoupling capacitor. The circuit is shown in Fig. 6.

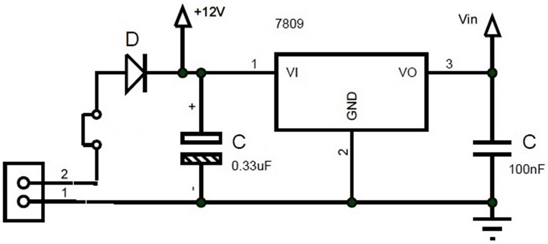


**Fig. 6.** Power circuit

## 4 Final Considerations

In the validation phase and model tests, we performed experiments in assembling the circuit in breadboard, via simulation software like Proteus, compatibility testing with Ladder Maker and adaptation to the changes made to the code.

After all the necessary adjustments throughout the development, we designed the printed circuit board, which is nothing more than a shield for the Arduino UNO, as shown in Fig. 7.

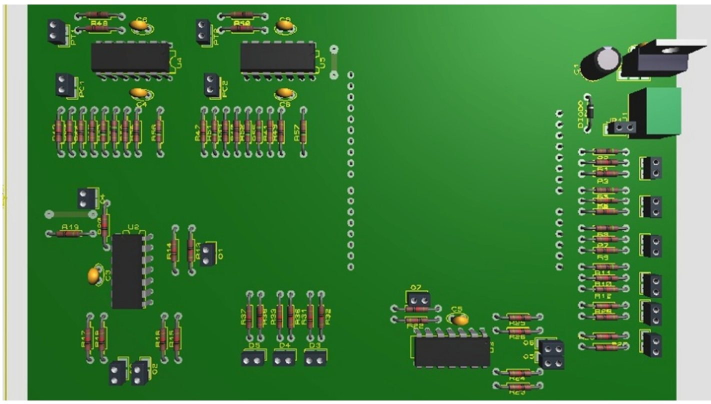

**Fig. 7.** Printed circuit board

By reducing the economic obstacles and by allowing more user-friendly interactions, it is relevant to apply this device as a tool to support the students of the basic cycle of the Engineering course. Hence, the students would be involved from an early age with their future profession, which would be beneficial for the development of their abilities.

To sum up, we believe that this electronic device can contribute to facilitate the access and expansion of engineering education, especially in the large area of Electrical Engineering.

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## References

1. Belhot, R.V., Figueiredo, R.S., Malavé, C.O.: O Uso da Simulação no Ensino de Engenharia, Cobenge (2011)
2. Silva, L.P., Cecílio, S.: A mudança no modelo de ensino e de formação na engenharia, Educação em Revista (2007)
3. Segundo, A.K.R., Cocota, J.A.N., Ferreira, D.V.M.: Development of an educational tool for control engineering. In: 2015 IEEE Global Engineering Education Conference (EDUCON), Tallinn, pp. 594–601 (2015)
4. Segundo, A.K.R, Cocota, J.A.N., Hilário, R.Q., de Oliveire Gomide, V., Ferreira, D.V.M.: Low cost SCADA system for education. In: 2015 IEEE Global Engineering Education Conference (EDUCON), Tallinn, pp. 536–542 (2015)
5. Hsu, R.C., Liu, W.C.: Project based learning as a pedagogical tool for embedded system education. In: 3rd International Conference on Information Technology: Research and Education (ITRE 2005), pp. 362–366 (2005)
6. Hertzog, P.E., Swart, A.J.: Arduino - enabling engineering students to obtain academic success in a design-based module. In: 2016 IEEE Global Engineering Education Conference (EDUCON), pp. 66–73 (2016)
7. Esposito, W.J., Mujica, F.A., Garcia, D.G., Kovacs, G.T.A.: The lab-in-a-box project: an arduino compatible signals and electronics teaching system. In: 2015 IEEE Signal Processing and Signal Processing Education Workshop (SP/SPE), pp. 301–306 (2015)
8. Carneiro, M.L., Brito, L.C., Araujo, S.G., Machado, P.C.M., Carvalho, P.H.P.: Genetic programming applied to programmable logic controllers programming. IEEE Latin Am. Trans. **9**, 266–275 (2011)
9. Oliveira, J.V.P.: Desenvolvimento de uma Interface para Acionamento de Dispositivos e Aquisição de Dados Via Porta USB. Monografia (Trabalho de Final de Curso em Engenharia de Controle e Automação) - Escola de Minas, Universidade Federal de Ouro Preto, Ouro Preto, Brazil (2014)
10. Malvino, A., Bates, D.J.: Eletrônica, vol. 2, 7 edn. AMGH, Porto Alegre (2007)

# Conceptualising Design of Learning Management Systems to Address Institutional Realities

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**Abstract.** There is growing interest in the use of E-Learning in higher educational institutions. However, studies have shown mismatches between Learning Management System (LMS) design and the general institutional context in developing countries. In this paper, we assess the design and implementation requirements for Makerere University LMS against the overall institution context. This research follows a qualitative method (interviews) and uses case study. We employ the design reality gap model to investigate the design requirements of the LMS against current institutional realities. A design reality gap of 46 was obtained implying ad-hoc measures need to be put in place otherwise the failure/stagnation of LMS is eminent. The study concludes with the need to identify hybrid approaches to LMS contextualization including use of tactical plus Strategic Information system plan (SISP), selecting/building hybrid staff and blended learning.

**Keywords:** e-Learning · Learning Management Systems · Design reality gap

## 1 Introduction

There is a growing interest in the use of eLearning and the corresponding adoption of Learning Management Systems (LMS). This is aimed at enhancing teaching and learning in higher educational institutions. ICTs are tools for building knowledge societies and provide opportunities for redesigning the education systems (Albert and Mercedes 2010). To ensure ICTs' full scale use, organizations are increasingly focusing on online learning enabled initiatives. Therefore, incorporating eLearning within higher education is seen to offer benefits for both the developed and developing world. However, studies have shown that there could exist significant mismatches between LMS design and implementation requirements and the general institutional context in developing countries (Ssekakubo et al. 2011; Heeks 2002; Kasim and Khalid 2016). Whereas incorporating eLearning within higher education is seen to offer benefits for both the developed and developing world, the strengths of institutional realities supersedes the unprecedented opportunities that LMSes should offer. These mismatches could be emanating from the implementation of Information Systems (IS) based on the


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extremes of either social (soft) or technical (hard) neglecting the appropriate balance between the two constructs. There has been numerous research in the areas of LMS adoption, particularly covering the hard aspects of IS integration within the traditional educational systems. For example some research has focused on the integration of educational information systems (technical approach) as self-contained distributable objects (Learning objects) based on the standardization of IS designs (Torrente et al. 2009). This research is however engineering or technically centered to LMS implementation since it follows IEEE standardizations for learning objects (LO) for increased reuse across different LMS platforms and interoperability. Focusing on the technical aspects alone in implementing IS may not necessarily address the social context vital within an institutional ecosystem.

In contrast, proponents of social science research advocate for the integration of IS in existing educational systems following a soft approach. This approach recognizes the primary importance of people and social interactions in shaping successful LMS implementation (Mayoka and Kyeyune 2012; Opati 2013). For example, a research by Mayoka and Kyeyune (2012) based on the diffusion theory considers five soft aspects phased in stages including knowledge, persuasion, decision, implementation and confirmation. The soft approach however does not adequately account for the technical or technology centered aspects. However, research emanating from the pedagogists values the leading role of pedagogy in shaping sustainable educational systems as opposed to people and technology alone. One of the latest research on LMS implementation recognizes the leading role of E-Learning activities centered around instructional strategies, technologies and pedagogical models. (Aparicio et al. 2016). This research follows a hybrid path consolidating both hard and soft aspects in addition to people (Heeks 2006). In conceptualizing these aspects, we seek to answer the research question of how the design of the LMS and institutional reality affect the success or failure of the IS. In this paper, we will pursue to answer the research question by analyzing the design and implementation requirements for LMS against the overall institutional realities.

The remaining part of this paper is organized into four sections. In Sect. 2, we present the approaches and research methods used. Section 3, presents the findings and discussions of our work. We conclude with Sect. 4, summarising the outcomes and limitations of our research.

## 2 Research Approach and Methods

### 2.1 LMS in Makerere University

Makerere University the oldest higher education institution in Uganda has implemented more than three LMS' including Blackboard, KEWL, and Moodle. Since 1998, there have been several efforts to optimise distance education to more flexible modes of delivery. However, the development of LMS initiatives have yielded minimal success. Earlier initiatives were characterised with IS discontinuities, replacements and or stagnation without realising LMS' much anticipated benefits (Ssekakubo et al. 2011; Kituyi and Tusubira 2013). Blackboard for instance could not be sustained beyond donor support while Moodle has not yet registered its much-anticipated benefits despite being open source. Within a wider geographical context, the trend of E-Learning in other universities in Uganda, East Africa and beyond could take a similar shape with little or minimal considerable growth (Ssekakubo et al. 2011). Notably though, research suggest that Makerere University like other developing country higher educational institutions (DC HEIs) operates in an environment characterised with inadequate resources, management mishaps, frequent strikes and other volatilities among others. Therefore, assessing the development of success/failure of major institutional initiatives could provide valuable inputs in deciding the future growth of the university.

## 2.2 Research Framework

LMS can be deemed successful if all stakeholder groups attain their anticipated goals without undesirable outcomes. Identifying gaps in the implementation of LMS helps us to decide on future approaches to drive more effective e-learning initiatives. Recognising the need to measure the success or failure of information systems is important in deciding the most suitable LMS based on the institutional realities. In this study, we adopt the design-reality gap model Heeks (2002) (Fig. 1).

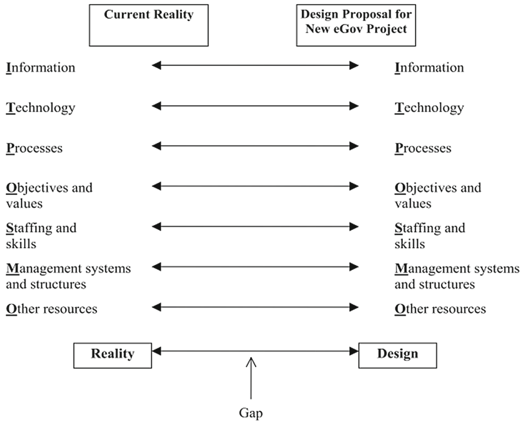


**Fig. 1.** Design reality gap model adopted from Heeks (2002)

The reliability and applicability of this model is high as it has attracted application in assessing major LMS project success and failures in developing countries in general (Heeks 2002; Munene 2015). The design reality gap model is based on the "ITPOSMO" dimensions which are regarded as applicable in contextualising any organisation IS defined as; information, technology, processes, objectives and values, staffing and skilling, management systems and structures, other resources (Heeks 2002). By rating the IS on ITPOSMO dimensions, it is possible to determine the degree of divergence or convergence of the IS towards success/failure on an established scale illustrated in Fig. 2. By summing all the scores obtained from the rating of the ITPOSMO dimensions, the result can be mapped on to the scale to inform the degree of success or failure of the IS in question. however, it is important to determine the extent of success/failure of the

IS as; total failure, partial failure and success. Total failure implies that the IS was implemented and immediately abandoned or was never implemented. Partial failure means that major goals for the implementation of the IS were not attained or there were undesirable outcomes. Success implies that major stakeholder groups attained their major goals and did not experience major undesirable outcomes (Heeks 2003). Important in this model is to judge the degree of convergence to zero or divergence away from zero as a measure of the extent of the design reality gap to depict the success of the IS.

| *Overall Rating* | *Likely Outcome* |
|---|---|
| 57 – 70 | Your e-government project will almost certainly fail unless action is taken to close design-reality gaps. |
| 43 – 56 | Your e-government project may well fail unless action is taken to close design-reality gaps. |
| 29 – 42 | Your e-government might fail totally, or might well be a partial failure unless action is taken to close design-reality gaps. |
| 15 – 28 | Your e-government project might be a partial failure unless action is taken to close design-reality gaps. |
| 0 – 14 | Your e-government project may well succeed. |

**Fig. 2.** The scale of rating success/failure of IS (Heeks 2002)

### 2.3 Research Methods

This study uses Qualitative methods (interviews and observations). Interviews were guided by semi-structured questions. A total of 8 respondents were interviewed with interviews lasting 1 and half hours. This was the done through the themes created from ITPOSMPO dimensions. Respondents were experienced E-Learning personalities in Makerere University. A case study strategy was used based on the institutional LMS. Interviews were further validated with email questions to minimize bias and allow respondents to freely express themselves on controversial topics. This data was triangulated with institutional literature to answer the research question. Three coders were used for inter-code reliability.

## 3 Findings and Discussion

The findings are presented using the design reality gap analysis. The design-reality gap analysis compares expected requirements within the LMS design with the institutional reality. The analysis is presented in ITPOSMO dimensions.

### 3.1 Information

The LMS system assumed that courses to be implemented on the platform were already designed, developed and customized. The system further assumed that appropriate instructional design approaches were used suitable for standardization of online programmes/courses. This is in resonance with instructional strategy and online pedagogical models for "onlinisation" of content based on the online context (Aparicio et al. 2016). The use of the LMS as a repository for simply sharing content implies that LMS is far from its design use. The absence of resources and failure for management to own the LMS initiatives has hampered development. LMS achieved a gap score of 8.

### 3.2 Technology

The design expectations assumed that there is integrated use of E-Learning technologies. Within the design, the system ought to have had a well-established e-course authoring and development environment and supporting hardware. The development of an ICT enabling infrastructure for educational support and wider industrial and service sectors remains a huge national challenge. One of the respondents was quoted "…ICT enabling infrastructure for educational support is a national challenge…". This was also in agreement with another respondent who said "…we still lack ICT infrastructure at Makerere University …". Makerere university in particular lacks adequate E-learning infrastructure to meet current LMS needs (Mayoka and Kyeyune 2012; Opati 2013; Mayende et al. 2015b). The gap score was 8.5.

### 3.3 Processes

The IS design assumed that teaching and learning would be offered as a minimum in a blended learning approach. According to the newly approved E-Learning policy, Makerere University has not yet fully operationalized E-learning since a proper roll out strategy for its implementation is yet to be agreed upon. A blended learning approach would consolidate both face to face and online learning approaches with each complimenting the other (Christian and François 2013). What is happening at Makerere could be far from blended learning since the traditional brick and mortar systems supersedes computer assisted learning. This leads to a high gap score of 8.5.

### 3.4 Objectives and Values

The system design assumed that the objectives for implementing the LMS were comprehensible to all stakeholders. However, Makerere University's E-Learning policy is yet to be implemented. The university is characterised with poor stakeholder relations hampering decision making (Tabaire and Okao 2010). Some senior staff perceive the system as increasing the negative impacts of MacDonaldisation specifically within the lecturing community. According to one respondent, some traditional University staff's attitudes restrain the culture of technology enhanced learning ecosystem. On the other hand, one respondent noted that the situation is not any different with some students familiar with brick and mortor education resisting change. This is out of phase with LMS design, specifically in terms of e-Learning activities as a result of contextualisation (Aparicio et al. 2016). Other proponents of pedagogy argue that there should exist continuous innovation in learning activities beyond 21st century skills of communication, creativity and digital literacy resulting from rapidly changing workplace contexts (Sharples et al. 2016; Mayende et al. 2015a; Mayende et al. 2016). This contradicts current realities giving a gap score of 7.

### 3.5 Staffing and Skills

The IS design assumed adequate skills for staff and students. Makerere University does not have a formal training programme for stakeholders for E-Learning engagement. However, there have been some efforts to by the university to develop its capacity in eLearning through donor funding. One respondent was quote emphasizing that Makerere University needs to recognise balanced student/staff formal skills development as fundamental to the success of LMS initiatives. Another respondent warned that failures could instigate major impediments in LMS development efforts. This created a medium design gap of score: 5.

### 3.6 Management Systems and Structures

The design proposed no real changes to pre-existing institutional structures and no significant changes to management systems. Since Moodle was replacing a commercial system, a proper management structure was already in existence that required adaptation to the new IS. This yielded a small design reality gap of score 1.5.

### 3.7 Other Resources

The design assumed that a separate budget already existed catering for at least two financing options. Makerere University is yet to allocate a budget for E-Learning. One respondent narrated that the University does not have a budget for eLearning. In another comment, a key respondent recounted that the institution is largely understaffed. This is cemented in what has been termed as “the malaise of Makerere University” since the institution remain largely financially constrained further affecting other operations with more than 50% of the university under staffed. The overall gap is medium with a score of 7.5.

### 3.8 Summary of ITPOSMO Scores

Table 1 is a summary of the scores from the analysis of the ITPOSMO data.

**Table 1.** Summary of ITPOSMO scores

| CODER | I | T | P | O | S | M | O |
|---|---|---|---|---|---|---|---|
| 1 | 8 | 8.5 | 8.5 | 6.5 | 5 | 1.5 | 7.5 |
| 2 | 7.5 | 7.5 | 9 | 7 | 6 | 2 | 8 |
| 3 | 8.5 | 9.5 | 8 | 8.5 | 4.5 | 1 | 7 |
| Average | **8** | **8.5** | **8.5** | **7** | **5** | **1.5** | **7.5** |

By mapping the overall score of 46 (Sum of average scores) to Fig. 2, this puts the total score in the range of 43–56 which implies that Moodle has an overall medium/large design–reality gap. This implies that the LMS will likely fail unless ad-hoc action is taken to close the gaps and make the design more like the reality.

## 4 Conclusions

We conclude that there is need for change in the current reality and making it more like the requirements with-in the LMS design through: Practicalising blended learning based on E-learning systems theoretical framework, developing strategic engagements that follow a tactical-plus SISP, selecting/building hybrid staff in key roles with both Information systems and management competences. The limitations of this research include subjectivity following case study research which cannot fully be mitigated even after data analysis is subject to more than research team in this case 3 members. The design reality gap model does not account for interrelatedness between the design reality dimensions yet these dimensions are not mutually exclusive.

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## References

Albert, S., Mercedes, G.-S.: The role of information and communication technologies in improving teaching and learning processes in primary and secondary schools. Australas. J. Educ. Technol. **26**(8), 207–220 (2010). https://doi.org/10.1080/09687769.2010.529108

Aparicio, M., Bacao, F., Oliveira, T.: An e-learning theoretical framework. Educ. Technol. Soc. **19**(1), 292–307 (2016)

Christian, D., François, O.: Developing countries in the e-learning era. Fundamentals of educational planning 096 (2013). http://unesdoc.unesco.org/images/0021/002180/218002E.pdf

Heeks, R.: Information systems and developing countries: failure, success, and local improvisations. Inf. Soc. **18**(2), 101–112 (2002). https://doi.org/10.1080/01972240290075039

Heeks, R.: Most eGovernment-for-development projects fail: how can risks be reduced? In: Climate Change 2013 - The Physical Science Basis, vol. 14, p. 4 (2003). https://doi.org/10.1017/CBO9781107415324.004

Heeks, R.: Implementing and Managing eGovernment: An International Text. SAGE, London (2006)

Kasim, N.N.M., Khalid, F.: Choosing the right learning management system (LMS) for the higher education institution context: a systematic review. Int. J. Emerg. Technol. Learn. **11**(6), 55–61 (2016). https://doi.org/10.3991/ijet.v11i06.5644

Kituyi, G., Tusubira, I.: A framework for the integration of e-learning in higher education institutions in developing countries. Int. J. Educ. Dev. Inf. Commun. Technol. **9**(2), 19–36 (2013)

Mayende, G., Isabwe, G.M.N., Muyinda, P.B., Prinz, A.: Peer assessment based assignment to enhance interactions in online learning groups. In: Paper Presented at the International Conference on Interactive Collaborative Learning (ICL), 20–24 September 2015, Florence, Italy (2015a)

Mayende, G., Muyinda, P.B., Prinz, A., Isabwe, G.M.N., Nampijja, D.: Online learning needs assessment in Uganda. In: Digital Media, Tools, and Approaches in Teaching and Their Added Value. Waxmann Publishers (2015b)

Mayende, G., Prinz, A., Isabwe, G.M.N., Muyinda, P.B.: Learning groups for MOOCs: lessons for online learning in higher education. In: Paper Presented at the 19th International Conference on Interactive Collaborative Learning (ICL2016), 21–23 September, Clayton Hotel, Belfast, UK (2016)

Mayoka, K., Kyeyune, R.: An analysis of e-learning information system adoption in Ugandan Universities: case of Makerere University business school. Inf. Technol. Res. J. **2**(1), 1–7 (2012)

Munene, S.: Application of the Design – Reality Gap Model to Enhance High Availability of Systems for Health Care Providers in Nairobi, Kenya. University of Nairobi (2015)

Opati, O.D.: The Use of ICT in Teaching and Learning at Makerere University: The Case of College of Education and External Studies. University of Oslo, 102, 37 (2013)

Sharples, M., Adams, A., Alozie, N., Ferguson, R., Fitzgerald, E., Gaved, M., Yarnall, L.: Innovating Pedagogy 2016: Open University Innovation Report 5. The Open University (2016). www.open.ac.uk/innovating

Ssekakubo, G., Suleman, H., Marsden, G.: Issues of adoption: have e-learning management systems fulfilled their potential in developing countries? p. 236 (2011)

Tabaire, B., Okao, J.: Reviving Makerere University to a Leading Institution for Academic Excellence in Africa Synthesis Report of the Proceedings of the 3rd State of the Nation Platform (2010). http://www.acode-u.org/Files/Publications/PDS_8.pdf

Torrente, J., Moreno-ger, P., Martínez-ortiz, I., Fernandez-manjon, B.: Integration and deployment of educational games in e-learning environments: the learning object model meets educational gaming e-learning and videogames. J. Educ. Technol. Soc. **12**, 359–371 (2009)

# Feasibility Study of Virtual Collaboration Concept of Academic Institutions from the Point of View of Students

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**Abstract.** Student mobility programs allow students to travel abroad and to attend part of their studies on foreign academic institutions learning to know other countries, cultures and people. It enhances personal development with priceless experiences and provides a unique opportunity to interact in international and multicultural environment. Yet, study exchange programs are limited to a relatively small number of applicants. Possible solution proposed recently, a concept of virtual collaboration and teaming among academic institutions across the globe, may provide the possibility of collecting multicultural and international experiences to a wider range of students. This paper analyzes students' attitude towards this concept.

**Keywords:** Virtual collaboration · Virtual teaming
Student exchange programs

## 1 Introduction

Higher education prepares students for working life [1] through acquiring of necessary knowledge and skills for execution of specific tasks connected to a specific profession. Besides the content of a study program, an academic institution offers several possibilities for professional development of an individual that may provide unique invaluable experience with significant impact on one's personality. A student mobility program provides challenges and possibilities for international students' self-formation and connectedness with the world around them as the intersections with new sociocultural environments, affects international students' identity and connectedness with place, people and values [2] and contributes to building of international and cultural tolerance. Studies abroad, exchange programs, and internships equip students with experiences and knowledge on how to understand, communicate, and successfully collaborate with each other across cultures [3]. Students apply for offered student mobility and other scholarship programs to travel abroad and to undergo a part of their study at a foreign academic institution, in different country with distinct mentality and culture. Participating and engaging in international and multicultural environment lead to higher appreciation of home cultural values, improve their understanding of various cultures and exploit their tolerance and respect towards others through increased acceptance of people with different attitudes and values [4]. The international and multicultural


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competence and tolerance represent invaluable abilities sought and needed in various facets of life. Organizations operating globally asses and evaluate levels of these abilities by potential employees and members already in application interviews. As the virtual collaboration is becoming a daily working practice in various companies, such an international and multicultural experience during an academic study may prepare students for their professional path.

The main disadvantage of student mobility programs is the limited number of students who can get a grant and use this unique opportunity to participate, travel, study local conditions, society, economics etc. at the source. A student exchange program provides the international and multicultural experience of high importance and with significant impact only onto a few students although all students may be in need of and be interested in it. The information and communication technology (ICT) allows providing the invaluable experience of interacting in international and multicultural environment to a wide public. It enables the access to such environment to all students. A concept of virtual collaboration and teaming among academic institutions across the globe enabled by ICT was proposed recently [5]. It intends to provide the opportunity of collecting multicultural and international experiences to a wide range of students. This paper aims to analyze its feasibility from students' viewpoint based on survey results showing their attitude to such a solution.

This paper is organized as follows: the next section briefly outlines the main idea of the concept of virtual collaboration proposed in [5]. Section 3 describes used methodology in conducted research. Section 4 provides research findings from conducted survey. Conclusion summarizes results and outlines areas of future research.

## 2 Brief Concept Overview

For the convenience of the reader, this chapter briefly describes the concept proposed in [5].

The proposed concept represents a possible supplement to the established study mobility programs. The limited access to mobility denotes a significant drawback. The proposed concept proposes virtual collaboration of students in a course among universities. Students build up teams where each member attends different academic institution. They work on assignments containing information about their countries and compare them among themselves. These assignments are elaborated in common collaboration platform.

In that way, students learn to know new people, nationalities and cultures; train their communication skills and foreign languages, etc. All the experience contributes to their international tolerance and may enrich their personal development with invaluable experiences that may be further exploited by their future employers.

The outlines of advantages and drawbacks as well as further information about use case scenarios can be found in [5].

# 3 Methodology

This paper deals with one aspect of feasibility study for concept proposed in [5], namely with the attitude of students towards proposed approach. This study provides results of surveys among students assessing their attitude towards virtual collaboration and teaming with students stemming from foreign academic institutions to mutually collaborate and work on course objectives. The questionnaire consisted of open questions regarding their experiences, opinions and attitudes regarding aspects analyzed in particular questions.

Respondents were divided in various categories based on presence or absence of their participation in student mobility program. It aimed to show the meaning of participation in virtual collaboration proposed by analyzed concept for students who already experienced an international student exchange program as well as the importance of opportunity of international virtual collaboration and teaming for students who have not participated in a student mobility program due to whatever reason.

Participants who underwent student exchange provide their experiences and viewpoint to participation on virtual teaming and collaboration as well as their assessment and perception of the impact of their international and multicultural experiences on their personal development. The survey asses their viewpoint towards the possibility of achieving such international and multicultural experience in virtual environment.

Students who have not participated on student mobility program provide their reasons for not using this possibility and their attitude towards virtual collaboration with students of foreign academic institutions. The expected major reason may be the limited amount of places for a study exchange program or local obligations.

# 4 Findings

For the convenience of the reader, various aspects analyzed by the survey are divided into individual subsections providing questionnaire results.

## 4.1 Reasons for Non-participation in Student Mobility

Students have not yet undergone any student mobility gave following main reasons for their non-participation:

- Unpreparedness to travel abroad on their own;
- Late reacting to submission deadlines for applications;
- Overloading with initial organizational conditions regarding the academic study itself;
- Unavailability of student positions for mobility during bachelor study (majority of available universities offer student mobility mostly for master study programs).

The majority of respondents (Fig. 1) expressed their concerns on using the opportunity of participating in student mobility programs and plan to apply for a student mobility program next year. The minority adduced as reason for their disinterest their private obligations in sport activities that do not allow them to travel abroad as the training cannot be interrupted.

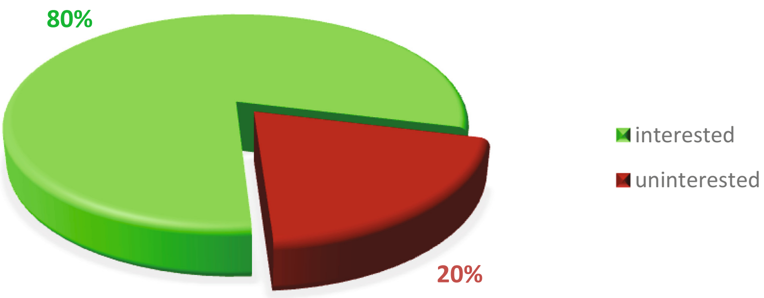


**Fig. 1.** Interest in student mobility programs

## 4.2 Attitude Towards Virtual Collaboration and Teaming

Half of responding students in the first year of their studies were not acquainted with the term and the meaning of "*virtual team*" and cannot take any position toward international and multicultural virtual collaboration and teaming. Second half of respondents expressed positive attitude toward collaboration and teaming with people from other countries in virtual environment (Fig. 2).

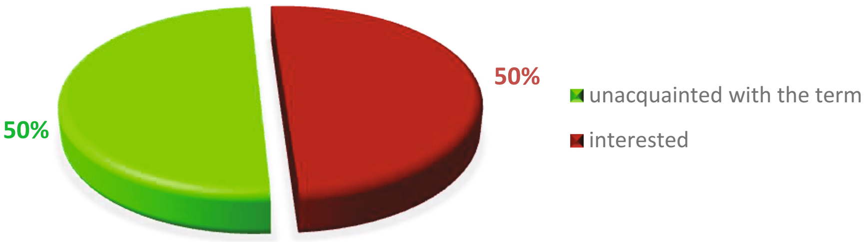


**Fig. 2.** Interest in virtual collaboration and teaming of students of 1st grade

As major reasons for interest in such collaboration following topics were given by participating students:

- Learning to know new people;
- Practicing language skills and improving the level of international competence in foreign language;

The possibility to work and participate in global international and multicultural environment was appreciated and given as the reason for interest in engagement in virtual collaboration and teaming.

Responding students of the 4th year of their studies (the first year of their master program studies) understood and perceived the term of virtual collaboration and team as "a traditional team except of common place, where members of the team can collaborate remotely by utilizing virtual forms of communication {e-mail, chat, videoconference}, usually communicating through a web interface" (source: survey). All respondents (100%) expressed their interest in such an international and multicultural virtual collaboration and teaming with foreign students from diverse universities. As major advantages of such an opportunity in virtual environment, following factors were given by the respondents:

- Fast speed of communication;
- Flexibility (independence on place);
- Effectivity (reduction of induced costs, high time efficiency);
- Money saving (reduction of induced costs);
- Without unnecessary emotions that may complicate any cooperation;
- Working on different places in diverse times;
- Mitigating time and geographical barriers;
- Professional development;
- Communication with experts from around the globe;
- Improvement of communication skills in foreign language;
- Experience in virtual collaboration and teaming appreciated by bigger companies (advantage for job applications).

Respondents also expressed their concerns regarding virtual collaboration and teaming that may be negatively impacted by various adverse effects. Following reasons were given by respondents:

- Complicated problems are sometimes solved faster and better at personal encounters;
- Less confidence and mutual trust among team members;
- Cultural differences leading to misunderstandings based on insufficient language comprehension and different cultural background;
- By rule, virtual teams are perceived less effective than traditional locally assembled teams;
- Delaying through postponed or suspended responses and late execution of tasks;
- Incorrect selection of communication channel for discussions and problem solving;
- Absence of personal contact and social isolation;
- Less control of goals achieved;
- Dissonance in understanding and comprehension of tasks, messages, etc.

## 5 Conclusions

The development of ICT has provided new ways of communication and processing across the planet. The collaboration and teaming in international and multicultural environment are already used on a daily base in business life, academic world as well as in governmental sector. Students of academic institutions are offered to travel abroad through student mobility programs and to learn to know diverse cultures, countries and people. The exposure to diverse cultures and nations and the ability to handle properly such encounters are skills that are sought and strongly appreciated by future employers.

However, the gaining of such priceless and unique experiences is restricted only to a limited number of participants. Exploiting ICT possibilities, the opportunity to operate and collaborate in international and multicultural environment can be offered to a much broader group of students making it possible for everyone to gain such a unique and invaluable experience. Recently a concept model of such collaboration has been proposed [5]. A survey examining one aspect of its feasibility through identifying and analyzing the attitude and interest on students' side has been conducted showing significant interest of students towards such a possibility. The survey was conducted among students of various years of university studies at one university providing insights to students' point of view.

The utilization of ICTs in courses of academic institutions to provide international and multicultural environment for virtual collaboration and teaming may provide the opportunity of developing international and multicultural skills to a broader group of students that represent an invaluable experience of significant importance to individual personal development and denote collaboration of high interest to students and graduates. At the same time, it may improve the active participation of students in courses [6] as utilization of ICT and multicultural collaboration represent a strong motivational factor that may positively influence the attitude of students towards the academic study and learning.

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## References

1. Nyström, S.: The dynamics of professional identity formation: graduates' transitions from higher education to working life. Vocat. Learn. **2**(1), 1–18 (2009)
2. Tran, L.T., Gomes, C.: Student mobility, connectedness and identity. In: Tran, L.T., Gomes, C. (eds.) International Student Connectedness and Identity. Cultural Studies and Transdisciplinarity in Education, vol. 6, pp. 1–11. Springer, Singapore (2017)
3. Popov, V., Brinkman, D., van Oudenhoven, J.P.: Becoming globally competent through student mobility. In: Mulder, M. (ed.) Competence-Based Vocational and Professional Education, Technical and Vocational Education and Training: Issues, Concerns and Prospects, vol. 23, pp. 1007–1028. Springer International Publishing (2017)
4. Gu, Q., Schweisfurth, M., Day, C.: Learning and growing in a 'foreign' context: intercultural experiences of international students. Compare **40**(1), 7–23 (2010)
5. Dávideková, M., Greguš ml., M.: Concept proposal for integration of virtual team collaboration in a university study subject. In: Kapounek, S., Krůtilová, V. (eds.) 20th International Conference Enterprise and Competitive Environment 2016 (2017, in press)
6. Veselý, P., Karovič, V., Karovič ml., V.: Investments in education as a benefit for e-government. In: Drobyazko, S.I. (eds.) Economics, Management, Law: Innovation Strategy. Henan Science and Technology Press, Zhengshou, pp. 280–284 (2016)

# Teaching Aviation Engineering with Remote Access to Physical Systems

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**Abstract.** This paper presents an alternative teaching method through a virtualized remote laboratory for engineers in aviation, mechanics, control and analytics. In practical conditions, it is difficult for students to access a physical turbojet engine in a testing facility and study its operation on-site. Either the operation rooms lack the space for observers and operators, or only some specific personnel are permitted to access the operation room, thus rendering the students unable to gain practical experiences on-site.

Our goal is to provide a set of applications to enable students' passive and active remote access to the turbojet engine testing facility. To achieve lowest network traffic possible in real-time, we use TCP and UDP protocols. We tested the throughput of this solution with a distribution server but some testing from the students' point of view is also necessary to obtain suitable feedback.

**Keywords:** Remote access · Physical systems · Turbojet engine
Testing facility

## 1 Introduction

Current progress in virtual and augmented reality offers a lot of opportunities to design creative ways of studying different technical aspects of physical systems. One of the forms of virtual reality is the virtual presence or, in other words, the remote presence. In cases where the student is unable to attend a specific class, the utilization of mentioned aspects of virtual reality seems promising. It is also possible to include the inability to enter a specific building or room due to security precautions into this group of presence related problems. In case of the topic of this paper, the virtual presence is related to a turbojet engine testing facility (see Fig. 1). For all engineering degrees, it is vital to have


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contact with a real-world system during studies, to obtain at least basic practical experience. It is also a place to apply theoretical knowledge gained during lectures and numerical exercises.

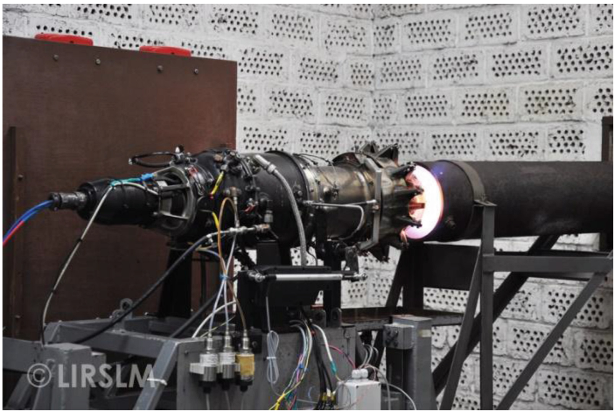


**Fig. 1.** Engine testing facility (view from inside the test room)

Our main goal is enabling remote virtual access to the engine testing facility for aviation, mechanical, control and data engineering students to provide a practical environment for observing thermodynamic and operational characteristics or mentioned physical systems. Particular properties of such an environment do not allow a fair extent of in-person participation, mainly due to lack of space, security issues and possible chemical and acoustic exposure of people in the command room and the testing room. Usually 2–5 people are physically present in the command room during launches and other tests. Although some students have become members of the research team because of the topic of their final thesis, other students may receive only a limited amount of interactive information (and interaction) regarding the engines' operation. This leads to the necessity to create a suitable form of providing interactive information for all aviation engineering students.

## 2 Description of Target Audience

The remote access should provide usable information for teaching in at least four separate engineering programs at the Technical University in Košice at once.

1. Avionics – is an electrical engineering program mostly oriented on aviation electronics including embedded systems, communication, controllers and software systems in avionics. Students from this engineering programs would benefit from remote access to a turbojet engine because of i.e. a possibility to observe real-world sensor settings a possibility to calibrate a specific sensor, and observe different results with different avionic software settings and conditions.

2. Aviation engineering – is a mechanical engineering program oriented on construction of aircrafts, their systems, subsystems and elements. The program also contains creating different control algorithms for specific aircraft systems. In this case, students would benefit from observing real-world reactions of the engine in its borderline conditions or if it encounters a non-typical situation. They can propose and test different control algorithms or tune parameters of the existing algorithm, run a simulation on the hardware or observe its results during a launch.
3. Cybernetics and artificial intelligence – is a computer engineering program that concentrates on systems' control, alternative and intelligent control algorithms. Students would benefit from a possibility to propose and create alternative control algorithms with a specific aim on efficiency, reliability or safety of the engine.
4. Business information systems – is a computer engineering program, the orientation of which is mainly on development of information systems, data processing and analysis. Students of the business information systems program can use the live data stream as a real-world source for learning data stream analysis, real-time classification, outlier detection, data filtering, etc. Such real-time data source proved valuable over time because of its rapid volume growth (size of a single sample and transmission speed) in a short time period.

### 2.1 Pedagogic Scenario

The iSTC-21 V turbojet engine is a state-of-art system developed as an instructional and research tool by carrying out various construction modifications [1] to soviet era TS-21 auxiliary power unit used in various soviet made military fighters like MiG-23, MiG-27, SU-7, SU-20, SU-22 and other. With mentioned modifications, the engine became a conventional turbojet (gas turbine) engine, however small scale. This means that its operating costs are small enough for it to be used in teaching and research. It is obvious that auxiliary elements of such an engine also used the former procedures, algorithms and were mainly mechanically controller. The main purpose of the research and later the teaching is to provide enough possibilities for students to differentiate between mechanical fuel supply and digitally controller fuel supply. With the ability to provide information from the engine's operation using the mechanical and digital control, the students can learn the differences between the two. Moreover, the usage of alternative intelligent and modern algorithms allows them to see the future prospects of fuel system and engine control. This is the space for students to propose modifications, novel approaches to control, modify and suggest improvements for live experimenting with the ability to see the data off-site and in real-time.

## 3 Previous Work and Current State

According to previous surveys done in [3], the problem of remote presence (virtual laboratory) in our conditions can be decomposed into two separate problem sets.

- passive access to the system - remote monitoring,
- active access - modifying some selected parameters of the system or limited interaction with the system

Due to security concerns a remote user with active access cannot be granted full control of the system. There are two main reasons for this limitation.

1. Network failure – if the network connection is dropped or severely unstable, the local control system of the engine would need an automatic power off switch. Its implementation would be simple but in case of a turbojet engine, its stalling in particular running sequences (i.e. during launch or acceleration [2]), specific mechanical components could suffer from overrated load. The best-case scenario is that the engine runs out of fuel and only the fuel/oil pumps will be damaged due to overheating with no transport fluid to cool them down. On the other hand, the worst-case scenario is that with no network connection whatsoever, the engine could uncontrollably accelerate. This would lead to cavitation (turbine dissolution due to excessive heat and stress) and later to fast plastic deformation (explosion of the turbine disc or blades), which would damage the entire engine and possibly some surrounding systems.
2. Remote operator's mistake – local observation of the test room through a reinforced window allows the personnel to closely monitor the situation inside the room. Not only the engine but also other essential elements (fuel/oil system and pumps, power supply, fuel levels, etc.) of the system need to be in sight during testing procedures. It is also necessary to monitor acoustic behavior, sparks in the output flames and other possibly dangerous events, that are very hard to reproduce remotely in the same quality, in which they can be observe locally. Mentioned facts prove that in case the operator makes a mistake in the control algorithm or launch procedure, it is less possible to react in time if the observation of the operator is limited to camera streams.

In our previous paper [5], we proposed a scheme (Fig. 2) for carrying our passive access by creating a set of applications that mutually communicate at the transport layer of the ISO OSI model. Particularly, the UDP transport layer protocol was used as a lossy way of fast, although unreliable data transmission. UDP is ideal for this purpose, because the audio/video streaming and data streaming (visual dashboard) are not affected by small packet loss [6, 7]. On the other hand, active access would require lossless TCP protocol [8] to ensure all instructions are transferred correctly. To prove this hypothesis, we carried out a load test, as well as a network throughput and latency tests [3].

Our solution, described in [5], included a local unicast transmitter a load balancing server and a client application (website).

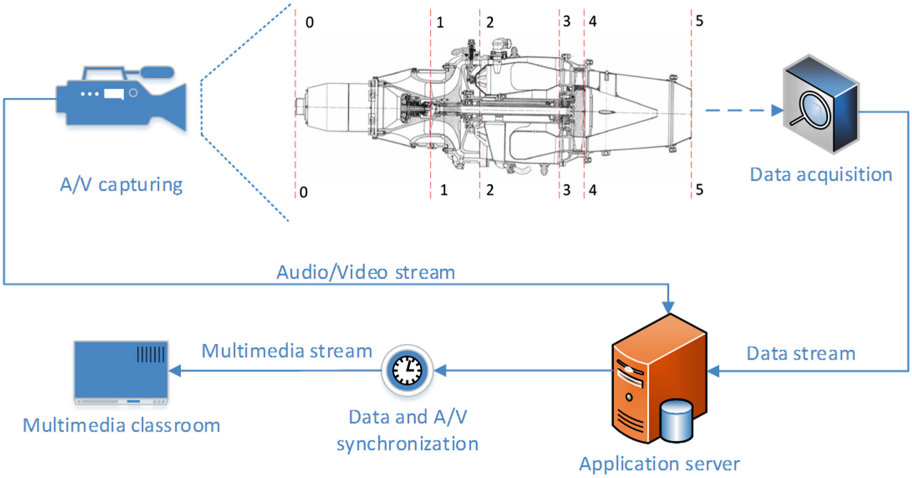


**Fig. 2.** Simplified remote monitoring scheme

## 4 Future Work and Expected Results

The remote monitoring has not yet been tested in the teaching conditions but we are planning to do so in the following semester. One missing element of the mentioned proposed scheme is the camera array, which will be mounted, installed in the testing facility and integrated into our remote monitoring applications the following semester as well. Currently, the remote end user can only see a dashboard (see Fig. 3) without any other real-time multimedia content on his PC screen.

**Fig. 3.** Dashboard of the client remote monitoring application

Other possibility to enhance the overall experience and teaching possibilities is to capture and forward high quality acoustic samples from a microphone array. Although this opportunity has not yet been addressed, several experiments were conducted [1, 4], to prove that it is possible to detect unwanted behavior or different engine's components using spectrographic analysis of the sound. Such data can be used to teach pattern recognition, analogue signal processing or stream data mining and test the resulting models in the operational conditions as alternative diagnostics. We are providing a comparison between the RPM of the engine's compressor during launch and the audio spectrogram captured by a single microphone in Fig. 4 as a proof of concept.

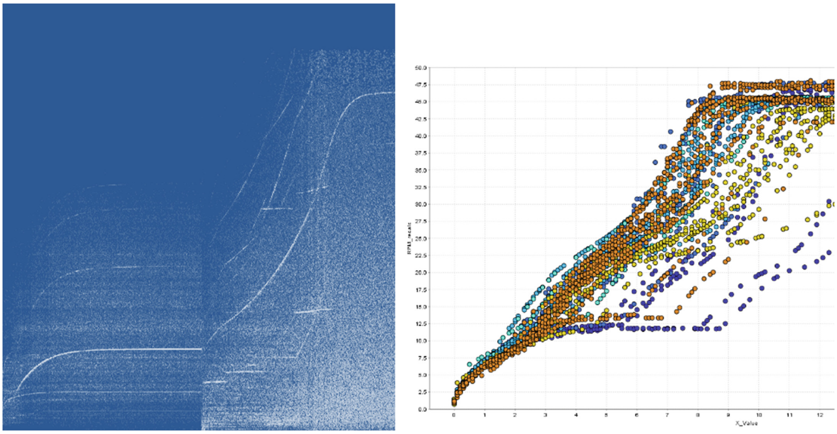

**Fig. 4.** Audio spectrogram of the engine compressor's RPM during a single launch (left), multiple measurements of compressor's RPM during launch (right)

As stated in chapter 2, the tasks of the experimental testing will be conducted on students from different study programs with different views on the engineering field. We are planning to conduct a survey (rating) about the positive and negative aspects of the remote monitoring system. We will consider the monitoring applications successful if at least 70% of the feedbacks are positive regarding the technological and the theoretical enhancement of their knowledge after the semester. After the implementation of active access (sensor calibration and access to working control models), we expect to do a similar survey, once the students test the solution. We will consider the active access applications successful, if at least 70% of the involved students' feedbacks are positive.

## 5 Conclusion

In the last three years, we have created several mostly technical studies, to gain enough information about the possibilities of creating a virtual laboratory out of a physical laboratory using virtual remote presence. We addressed the way of data and audio/video transferring [5], the possibilities of network failures in the current local LAN conditions [1, 3] and latency and load tests [3] to scale the infrastructure accordingly.

Lately, we created a set of applications for remote monitoring, considering all previously mentioned studies. The remote monitoring client will also be accessible on the internet (besides the local LAN) once the local tests are completed on students of four different engineering programs.

We also addressed the need for remote active access and mentioned the drawbacks and dangers of this approach.

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## References

1. Lazar, T., Madarász, L., Gašpar, V.: Estimation process analysis of identification efficiency of a small turbojet engine with intelligent control. Elfa, s.r.o. Košice, 160 pp. (2013). ISBN 978-80-8086-200-8
2. Madarász, L., Karoľ, T., Gašpar, V., Andoga, R., Főző, L., Judičák, J.: Digital start-up control of the small turbojet engine MPM-20. In: 10th IEEE Jubilee International Symposium on Applied Machine Intelligence and Informatics (SAMI 2012), Proceedings, Herľany, Slovakia, 26–28 January 2012, Budapest, pp. 277–281. IEEE (2012). ISBN 978-1-4577- 0195-5
3. Madarász, L., Gašpar, V., Rudas, I., Andoga, R., Gašpar, Ľ.: Proposal of dissemination and broadcasting of laboratory data within small time latencies. Acta Mechanica Slovaca **17**(3), 26–32 (2013). ISSN 1335-2393
4. Gašpar, V., Madarász, L., Andoga, R., Karoľ, T., Főző, L., Judičák, J.: Replacement impacts of MPM-20 turbojet engine using measured data analysis. In: 14th Conference of Doctoral Students (ELITECH 2012), 22 May 2012, Slovenská technická univerzita v Bratislave, Bratislava, 6 pp. (2012). ISBN 978-80-227-3705-0
5. Gašpar, V., Andoga, R.: Remote real-time monitoring of a small turbojet engine. In: CINTI 2016 (2016)
6. Zhou, W., Li, Q., Caesar, M., Godfrey, P.B.: ASAP: a low-latency transport layer. In: ACM CoNext 2011, 6–9 December 2013, Tokyo, Japan (2013). ISBN 978-1-4503-1041-3
7. STANDARD - RFC 768. User datagram protocol, J. Postel ISI, United States of America (1980)
8. STANDARD - RFC 675. Internet transmission control protocol, V. Cerf, United States of America (1974)

# Introduction and Implementation of a Multi-leveled E-learning Environment Based on the Open Content Development Model Principles

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**Abstract.** In our paper we introduce a new multi-leveled e-learning environment, called Sysbook. It is an open-access surface, available on the internet for any users. Its main topic covers the field of systems and control, some mathematical and even philosophical sciences. The purpose of the Sysbook is to present systems and controls on different levels, addressing readers of different backgrounds and interests. There are four surfaces (levels): "Comics", "What we are talking about", "Control course" and "Mathematical representations, examples". In the same time two of them are displayed on the screen. These surfaces are extended with case studies for different fields and a student area where the users can also contribute. We would like to show that this conception can also be used in other fields of interest.

**Keywords:** Multi-level · E-learning · Environment · Systems · Control

## 1 Introduction

Nowadays it is getting harder to convince our student to read and study from the written books or notes. For the engineering students it is much harder when they should learn subjects where complex material is taught [1].

At the Hungarian Academy of Sciences Institute for Computer Science and Control we have started the development of a multi-leveled e-learning environment called Sysbook for two purposes, firstly to everybody; for the undergraduate students, for the experts with different professions or for the control specialists, secondly for our students at Budapest University of Technology and Economics who study Control Engineering course. Sysbook is available at: http://sysbook.sztaki.hu [2].

## 2 Conception of Sysbook

The idea, dating back for more than a decade, was to present the main principles governing systems and control on different levels. [3] In Sysbook there are four surfaces (levels): "Comics", "What we are talking about", "Control course" and "Mathematical representations, examples". There are altogether almost 140 pages, in 11 different


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chapters. In the same time two of them are displayed on the screen. While "Comics" and "What we are talking about" levels are available for every pages of Sysbook, the remaining two levels are explained only for special topics.

"Comics" is a cartoon-like level, some pictures, drawing with some words. A few of the pages includes animated comics also.

Then "What we are talking about" level gives the explanations of these pictures with detailed texts.

"Control course" contains the differentiated material which required for our Control Engineering students.

Finally "Mathematical representations, examples" explained the topics in deeper approach for the control specialists.

Sysbook is also including a glossary popup dialog for the new concepts and specific words. These words are highlighted in the text and when a user clicks on it, the explanation can be read.

We also made available a few case studies, also for different levels with different scientific fields to help the understanding, written by teachers and professors. These case studies can be used as separate material also.

We have also created a particular-surface to meet the Open Content Development model, called Student Area. Here the interested students can also upload any microcontents or case studies connecting to the presented topics. After a peer review these materials will also available as part of the Sysbook. Until now several students have submitted their contribution, all of them are available in the Student Area, some other contents are also under development [4].

We are going to use Sysbook in the following years also, to collect more and more interesting contents from our students and also to develop more functions and make better user experience by using the newest internet representation technologies.

## 3 Contents of Sysbook

The Information and Communication Technology is illustrated by Sysbook's individual pages. These pages may appear on surfaces that are dependent on the reader's taste and interest [5].

Sysbook also supports serial and random access. Therefore, we have the option of page-to-page page browsing (and varying with the four pages), and we have the option of loading any related page or random page by hyperlinks in the text, jump menu, search menu, or table of contents.

Using Sysbook, users can navigate through the menu as Fig. 1 shows: skip to a specific page, search for a specific expression, return to the table of contents, and navigate to a specific page.

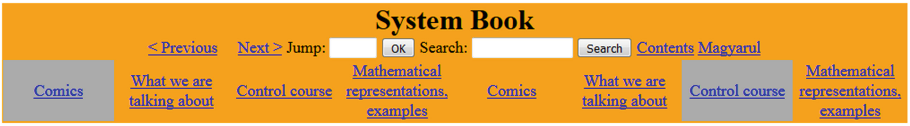


**Fig. 1.** The navigation menu at the top of Sysbook

In addition the environment is bilingual, so users can change the language of the interface from Hungarian to English on any page or from English to Hungarian by clicking the appropriate button on the menu. Each language contents are loaded from a separate database. The chapters of Sysbook can be seen in Table 1.

**Table 1.** Chapters of Sysbook

| | | | |
|---|---|---|---|
| 1. Every system: philosophy | 4. Representation of models | 7. Dimensions and spaces | 10. About the history of control |
| 2. Reality and its models | 5. Signals and systems | 8. Control, structures and algorithms | 11. Mathematical – computational representation |
| 3. Model building in our minds | 6. Changes and conservations | 9. Artificial intelligence | – |

After browsing Sysbook, users reach the surface of the case studies, which can be found in a separate PDF file and can be opened in the browser. [6] The case studies of Sysbook can be seen in Table 2.

**Table 2.** Case studies of Sysbook

| | | | |
|---|---|---|---|
| Cooking | Energy production and distribution | Systems and controls in the human body | Economical systems |
| Driving a car | Oil refinery | Medical systems and health education | Feedback in education and upbringing |

On the next page, the collection of bold words with explanation can be found in tabular form. Finally, the bibliography of Sysbook closes the pages. Then we find ourselves back again on the Sysbook cover page.

## 4 Implementation of Sysbook

From the technical point of view, Sysbook combines original book-based and Information Communication Technology-based forms.

The Sysbook begins with a cover, continues with the impressum, than the table of contents. After a short prologue the users get the interactive display surface. Figure 2 shows the first page of Sysbook.

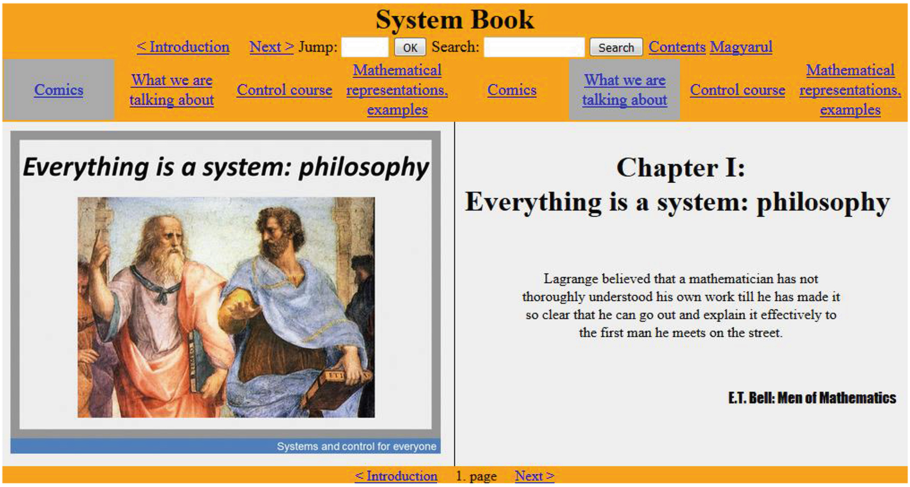


**Fig. 2.** The first page of Sysbook

After the pages at the back the case studies, glossary, and bibliography can be found. It is possible to switch between the pages using the navigation menu at the top and bottom of the site.

The previously listed static pages include the usual web page elements, such as paragraphs, images, hyperlinks, and external files.

The current 137 pages of Sysbook – for which there are always "Comics" and "What we are talking about" levels, and in many cases the other two levels of knowledge are also represented – are stored on the server side in a MySQL database.

Each level is located in a separate attribute, and the contents are stored in the records by HTML encoding. Using HTML code it is possible to store basic web formatting, such as different headings, paragraph formatting, bold, italic, underlined strings, lists, images, hyperlinks, embedded videos, or equations.

### 4.1 Comics Level

The "Comics" level can be used also as a separate material, as it is exported from a PowerPoint presentation and embedded in Sysbook, which helps with understanding with many images, graphics, little text, and sometimes animations. With JavaScript, the images are adapted to the settings of the screen and browser of the users.

### 4.2 The Other Levels

"What we are talking about", "Control course" and "Mathematical representations, examples" levels are loaded from the database to a PHP-based webpage [7]. The display interface has been supplemented with some features of interactivity.

One of the important additions is the MathJAX supplementation [8], which allows LATEX-based source code for equations [9] placed in HTML to be extracted and displayed (with further adjustment, such as zooming by right-click option).

The other addition is that there are explanations for the bold italicized words in the stored text, to which a comment appears in a popup window (with additional hyperlinks and occurrences) as Fig. 3 shows.

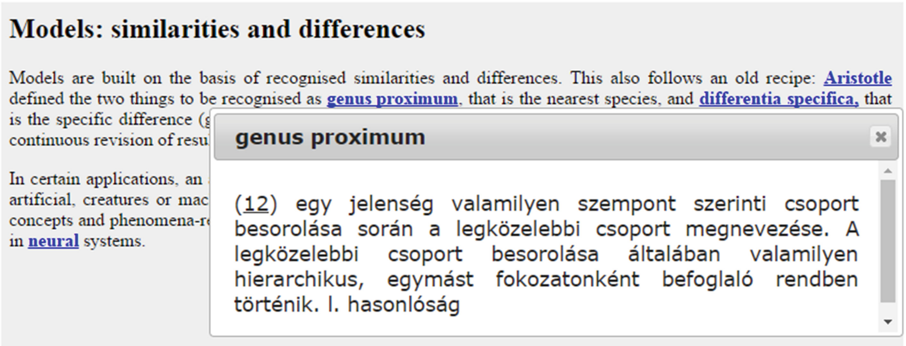


**Fig. 3.** An explanation of a highlighted word

## 4.3 Administration Interface

The administration interface of Sysbook allows editors to access various editing and administration pages. Following the open content development principles, Sysbook can be extended at any time and can be modified after the verification and the proofreading of the material.

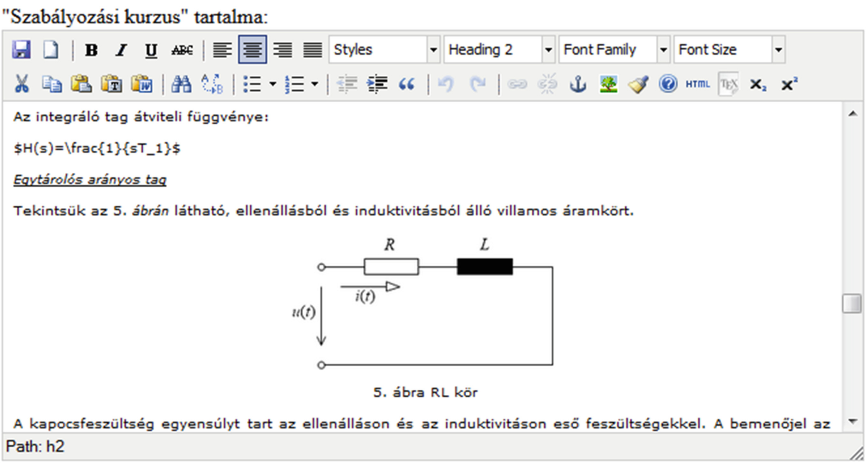


**Fig. 4.** TinyMCE-based WYSIWYG editor

On the “Comics” administration page it is possible to upload or change the comics for each page.

For the other levels a simple web editing interface has implemented. Figure 4 shows a TinyMCE-based editor [10], providing a user-friendly way to easily formatting and by the WYSIWYG feature (What You See Is What You Get) giving an immediate feedback on the format.

## 5 Sysbook as a General Environment

In Sysbook, we expect quality content related to the previous chapters to fit into the concept. Another option is the Student Area (with a separate database) where fewer, smaller content, examples and case studies can be uploaded by the students [4].

In the future, we would like to further expand Sysbook, for example, from Youtube, embedded training videos, and reader-clickable interactive applets. Nowadays we are working on implementation of these interactive applications which help to understand the systems and controls by clickable variable parameters and interesting illustrations.

We have also used Sysbook in Vocational Teacher Training on a specific course called System Theory [1] and we would like to extend the recognition of Sysbook in the academic field, by creating a general conception and implementation of it. Our plan is to make the “heart of Sysbook” (the source code, the database structure, installing options) portable, so everyone could install the multi-leveled e-learning environment, manage it, and upload any learning or other materials to it.

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## References

1. Benedek, A., Molnár, G.: New approaches to the e-content and e-textbook in higher education. In: Gómez Chova, L., López Martínez, A., Candel Torres, I. (eds.) INTED2015 Proceedings: 9th International Technology, Education and Development Conference, Madrid, Spain, International Academy of Technology, Education and Development (IATED), pp. 3646–3650 (2015). ISBN: 978-84-606-5763-7
2. Sysbook website. http://sysbook.sztaki.hu. Accessed 22 May 2017
3. Vámos, T., Bokor, J., Hangos, K.: Systems - governing principles and multimedia/CD/. In: 14th IFAC World Congress, Beijing, China, PT-5, p. 79. Plenary Lecture (1999)
4. Benedek, A., Horváth, J.Cz.: Case studies in teaching system’s thinking. In: Huba, M., Rossiter, A. (eds.) 11th IFAC Symposium on Advances in Control Education (ACE 2016), Bratislava, Slovakia, Preprints, IFAC, vol. 49, no. 6, pp. 286–290 (2016)
5. Vámos, T., Bars, R., Sik, D.: Bird’s eye view on systems and control – general view and case studies. In: 11th IFAC Symposium on Advances in Control Education (ACE 2016), Bratislava, Slovakia, IFAC-PapersOnline, vol. 49, no. 6, pp. 274–279 (2016)
6. Sysbook case studies. http://sysbook.sztaki.hu/esettanulmanyok_en.php. Accessed 22 May 2017

7. PHP website. http://php.net. Accessed 22 May 2017
8. MathJAX website. http://www.mathjax.org. Accessed 22 May 2017
9. LATEX website. https://www.latex-project.org/. Accessed 22 May 2017
10. TinyMCE website. https://www.tinymce.com/. Accessed 22 May 2017

# The Correlation Between Concepts of Resilience and Remote Experiment in Education

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**Abstract.** The role of virtual environment in relation with the resilience concept of has not yet been analyzed in depth. Educators cannot determine the resilience level of students as the trademark earned or inherited. But instead, they can create the educational conditions, enabling the resilience manifestation at higher level when the circumstances requires. The remote experiment, as a component brought in education by the virtual environment, are included in the present analyze, with them relevant benefits. The paper illustrates the fact that the problems, generated by the educational environment that aims at resilience education, are partly satisfied by the virtual environment qualities. Was succeeds to illustrate that the virtual environment (remote experiment) might contribute at resilience level increasing.

## 1 Introduction

The virtual environment has introduced in education new pedagogical tools and technologies. Their role in relation with the resilience concept [1–4] has not yet been analyzed in depth. Among the new tools and technologies introduced by the virtual environment authors chose the remote experiment. We will try to clarify its position in the frame of the current theories of resilience education [5–8] so as to reveal whether or not have a useful role in the process.

The issue of resilience, in the real environment, consists in the identification of resilient students and non-resilient ones using a series of factors [9, 10]. Prior to speak about these factors, firstly there is necessary to clarify the concept of resilience. Resilience includes processes and parameters designed for limitation of negative responses of students faced with three categories of phenomena (Masten, Best and Garmezy 1990) [11]:

– those regarding the differences existed between students put in front of a rapid recovery after educational traumatic effects;
– those regarding the obtaining of some unexpectedly good results in spite of negative predictions determined by events with educational risk;
– those regarding the manifestation of special adapting abilities in conditions of educational stressful situations.

The new approach regarding resilient themes in education stressed the need to consider the resilience as a process and not as a result. The authors accepted this approach in


M. E. Auer et al. (eds.), *Teaching and Learning in a Digital World*,
Advances in Intelligent Systems and Computing 716,
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the present analysis as a main starting point. This approach has revealed that the resilience in education must be analyzed not only in class or inside of the groups of students. It must be viewed to cover the whole range of possibilities using three levels:

– the individual level;
– the community level;
– the institutional level.

If educators cannot determine the students resilience level as the trademark earned or inherited, they instead can create the educational conditions enabling manifestation of the resilience at higher levels when the circumstances requires. The remote experiments, as a component brought in education by the virtual environment, are included in the present analyze, with them relevant benefits.

## 2 Resilience and Remote Experiment as Related Processes

Resilience viewed as a process, must be defined as the ability of an educational system to adapt permanently to the environmental changes so to ensure its functioning without affect fundamental characteristics (Manyena 2006) [12]. If we refer at the educational environment, it is recognized that it is conservative and that requires long periods of adaptation at the changes manifested in the socio-economic environment. The virtual environment appearance has changed this approach. In the education, the virtual environment plays the role of a dynamic component that responds quickly at changes occurred in the socio-economic environment. If at the beginning of the interpenetration of the mentioned two media - educational and virtual - the influence of the last may be neglected, today this it is no longer possible. The duration of the knowledge renewal rate was reduced and the vector that carries renewal there is the virtual environment.

Drawing a picture of resilience (as a process) components, is possible to analyze the remote experiment dynamic support in relation with these components. We can see that the above reflects the reality (Table 1):

**Table 1.** Resilience components reflected in remote experiment

| Nr Crt. | Components of resilience (as a process) | The resilience components reflected in the remote experiment design |
|---|---|---|
| 1 | Accepting the fact that educational systems must teach the student to work in **conditions of uncertainty** knowing that changes are inevitable in any process | *Remote experiments include intrinsic changes. These are generated by the endowment level of universities,(that is strongly reflected in the experiments level), by the level of the prerequisite knowledge of experimenters (as a consequence of the level of the graduated), by the speed of the Internet connection used, etc. All above means that the virtual environment itself contains elements of uncertainty determined by the modality of the remote experiment platforms building process* |

(*continued*)

**Table 1.** (*continued*)

| Nr Crt. | Components of resilience (as a process) | The resilience components reflected in the remote experiment design |
|---|---|---|
| 2 | Building the concept of educational resilience on the base of **diversity concept**, that means the multiple options offer for achieving the same objective. So is allowing easy adaptation to disturbances and is offering the minimization of the risk | *The network with remote experiments contains conceptual diversity. For the same phenomenon there will be multiple options for experiment implementing so that, will be satisfy the concept of diversity* |
| 3 | Contacting as many **types of knowledge** through exchanges, creating platforms for presentation of all existed surveys in educational environment. It will stimulate learning and innovation and will provide good ways to be followed in situations of crisis | *Platform(s) for presentation of all remote experiment solutions existed in the field. Any customer have the possibility to choose a path in these platforms so that the adaptation at change will be easy* |
| 4 | **Reorganization and renewal** are essential parts of natural cycles of change. Education institutions and academic communities must develop own strategies to put them into practice | *Platforms with remote experiments are so dynamic due the permanent embedding of the latest achievements from anywhere in the world. This embedding formed the pillars for strategies of change* |
| 5 | **Quickly adaptation** to the change ensured a dynamic educational environment. It is prepared to provide new answers and new educational buildings. For this we must pay particular attention to the self-organization process | *Remote experiment can be simple or very complex. Usually, the networks with remote experiments, covers all stages, from simple to complex, due the diversity in equipment and knowledge of those who compose them. A network of remote experiments or, access to multiple networks provides an attainable higher purpose. The decisions about the route between variants belong to the student, and this reason introduces a kind of self-organization process* |

The data presented in the Table 1 illustrates the fact that the educational environment that aims at resilience, are partly satisfied by the elements of the virtual environment represented here by the remote experiment.

## 3 Education at Risk, Practical Principles

Virtual environment, represented here by remote experiment, acts directly on the student (the individual level) and also directly on the class (the community level). It introduces explicit practices of education at risk/change, as can be seen in Table 2:

**Table 2.** Remote experiment contribution for education for risk improving

| Nr. Crt. | Practical principles for improving education for risk/change | Contribution of remote experiment |
|---|---|---|
| 1 | **Knowledge** | *In comparison with institutions immobile curricula (kept fixed between two processes of accreditation) remote experiment, offered by networks, offers to the students a diversified knowledge because these experiments reflect directly the differences between curricula existed in the world. As noted in Table 1. diversity is a powerful weapon to adapt at risk (resilience)* |
| 2 | **Different cultural backgrounds** | *Platforms with remote experiments reflect different cultural backgrounds. The students, in contact with these different cultural backgrounds, are in touch with different principles of life and education, which represents a very good way to increase resilience* |
| 3 | **Enriching the technical and technological knowledge** | *Remote experiments are created in environments that reflect the technological and technical level of universities (communities). Platforms with remote experiment will illustrate this diversity. And is well known that the diversity offers to the users necessary skills for adaptation at risk* |
| 4 | **Collaborative learning and instructional conversation** | *The remote experiment is collaborative due its content.* ***First,*** *in the virtual environment, experimental works requires, to compensate any existed gaps in knowledge, interaction between disciplines.* ***Secondly****, since remote experiments include theoretical notions, hardware and software used will reflects the manner of thinking. The students who will use these remote experiments are obliged to be in line with this manner of thinking. This alignment can be done only in collaboration manner with learning through instructional conversations* |
| 5 | **Learn to approach decisive actions** | *The remote experiment does not act in adverse situations. It support with the experiments theoretical courses. The theoretical material changes some times faster than its practical support. So, the remote experiments, offered in dedicated platforms, will serve only partially to the course goals. Decisive action, in this case, is to design and develop new remote experiments, in line with the new theoretical content. This decisive action is difficult because it often cannot be accomplished by one person. It need* |

(*continued*)

**Table 2.** (*continued*)

| Nr. Crt. | Practical principles for improving education for risk/change | Contribution of remote experiment |
|---|---|---|
| | | *establishment of collaboration between multiple users. This aspect of the collaboration is beneficial, from the point of view of resilience, because it meets with the requirements of the above 3 and 4 paragraph* |
| 6 | **Use a positive way to evaluate yourself** | *Remote experiment does not answer at this principle. To be fulfilled, the designer of the remote experiment must be approach it in deliberately manner, offered so an experimental setup which increase student confidence in own practical abilities* |
| 7 | **Look at things in the long run** | *Remote Experiment does not respond to this perspective* |
| 8 | **Work with a positive outlook on things** | *Remote experiment does not respond at this requirement* |
| 9 | **Use any opportunity for self-discovery** | *The vulnerability in the face of remote experiments is linked with the gaps in knowledge (software and hardware). Instead maneuver to quit the experiment, the student must work to complete its knowledge at the level required by the remote experiment. In this case is possibly that the student to become, in time, a designer of some other similar experiments* |
| 10 | **Take care of own needs** | *Remote experiment to not meet this prospect* |

The Table 2 data analyze, shows us that some methods applied in the real world, with the goal to increase resilience in education, have not correspondence in the case of remote experiment as representative of the virtual environment (pos. 6, 7, 8, 10). As a result, the design of remote experiments with the purpose: *education at risk* needs to be focused towards introduction of an environment that enhances resilience. For this, the designers of the remote experiment must be taken into account three design patterns as you will see in the following:

## 4 Templates for Experiments Design to Increase Resilience

***The compensator model:*** (Donald, Lazarus and Lalwara, 2002, [13]), has the main goal to neutralize the effects of possible risk factors. Risk factors in education can be created, for example, by the sudden change of rules in academic year graduation or by the sudden change of the rules of admission. In the case of graduation rules changes, remote experiments should be targeted mainly at experimental supporting of the generally valid theories that are not affected by changes in curriculum, and that allows rapid adaptation to the new environment. In the case of rules of admission changes, prerequisite knowledge should also refers at universal laws. The education based on the universal laws gives to the student the feeling that, no matter what changes in the system will be happen, their knowledge will ensures the minimization of the risk factors.

***The challenge model:*** (Cook and Du Toit, 2005, [14]) has as the main goal education of accepting small failures. In the frame of this model, remote experiment will be designed with variations of paths, some of which lead to failures (e.g. wrong experimental results) and only one correct version. Thus the student gets used to the idea that some ways of investigation may lead towards failure and that perseverance leads to success, fact that well prepared him to be adaptable at risk.

***The protective factors model:*** (Friesan and Brennan, 2005, [15]) has as the main goal encouraging the interactive process in which the student is introduced together with a protection system (i.e. a system that has included human factors as tutor, teacher, chats). Protection systems, incorporated in the remote experiments at the stage of the design, alerts whenever the student take a wrong decision (which can lead to failure). This method minimizes the risk on the one hand. On the other hand, students will become dependent by the external actors of correction. The most important protective factor in the remote experiment is that who allows avoidance of the difficulties introduced by language (hence the importance of human factors mentioned above). Most remote experiments networks are built using the English language. For this reason at accession, risk factors may occur in reading, writing, comprehension, etc. This part of the remote experiment must to be carefully designed because the language difficulties can lead to rejection reactions, which cancels the effects of increasing resilience tracked through experimental practice.

Continuing the idea of the resilience as process approach, is obvious that, the education systems based on experiment, must developed based on four components. These components were arises by the fact that the education process is dynamic, and that the learning based on experiment is considering both the past and the future. The virtual environment, compared with the real ones, stress the fact that it can help strengthen the dynamic functions of the education (Table 3).

**Table 3.** Supplementary functions of virtual environment

| Nr. Crt | The component | The action in real system | Supplementary functions in virtual environment |
|---|---|---|---|
| 1 | **Uncertainty** | The students must be educated that changes are inevitable and that they must constantly adapt at changes | *Remote experiment offers many practical solutions for the same measurement. So the change is ensured by the diversity of experiments offered in the virtual environment* |

(*continued*)

**Table 3.** (*continued*)

| Nr. Crt | The component | The action in real system | Supplementary functions in virtual environment |
|---|---|---|---|
| 2 | **Different types of knowledge** | The student accessed platforms that contain different approaches for the same theory. So are created connections and is stimulate innovation by learning | *As stated earlier, remote experiment offers various solutions (hardware and software) for measuring the same process. In addition at this diversity is discussed not only approaches with different levels of knowledge to the same problem, but it is added the diversity of constructive solutions chosen for experiments fact that stimulates divergent thinking* |
| 3 | **Renewal and reorganization** | The student must find solutions for renewal and reorganization between old and new knowledge. This depends by the institution management. Often the old system is kept instead to be renewed or to be reorganized | *The remote experiment reflects the development in different stages of laboratories in various geographical areas. Implicitly it will reflect the levels of renewal and reorganization in the host institutions. Students have so the possibility of comparison analyses and criticism. The existed differences allows them o take conclusions, useful for resilience* |
| 4 | **Diversity** | Students must be educated to manifest multiple options. This helps them cope with perturbations and thus reduce risks | *Remote experiment offers multiple options for achieving assemblies. Diversity is an intrinsic property of remote experiments networks usefully for resilience education* |

## 5 Conclusions

1. The paper try to illustrate that the virtual environment can contribute at increasing of the resilience level;
2. Analysis of the education components resilience, when it is approached as a process, shows that the virtual environment, represented here by the remote experiments, has additional elements that reinforce the process of resilience education. At the same time there are parts of the resilience education that are not sustained by remote experiment;
3. In education for change/risk, virtual environment introduces explicit practices, fact that should be used in an increasing manner in the teaching process;

4. The analyze regarding resilience shows that remote experiment, as a part of the virtual environment, sustain and increase the requirements, considered usefully for resilience, in the real environment.
5. Following the above conclusion in the paper are presented the design models for remote experiments that can be used to improve their the effect in resilience education;
6. The paper presented comparisons, in binomial system *real – virtual,* between the education components that provide the process dynamicity, with direct effect to increase resilience.

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## References

1. Cayton, H.: Professional Standards, Resilience and Comparison. University of Westminster (2014)
2. Diprose, K.: Resilience in futile? Soundings 58 (2015). bit.ly/1EbBgFQ
3. Douglas, C.S.: The role of public education in governance for resilience in a rapidly changing. Ecol. Soc. **20**(3), 452–462 (2015). 29, http://dx.doi.org/10.5751/ES-07757-200329
4. Fekete, A.L., Tzavella, K., Armas, I., Binner, J., Garschagen, M., Giupponi, C., Mojtahed, V., Pettita, M., Schneiderbauer, S., Serre, D.: Critical data source; tool of even infrastructure? Challenges of Geographic information system and remote sensing for disaster-risk governance. ISPRS Int. J. Geo-Inf. (2015). ISSN 2220-9964, https://doi.org/10.1190/ijgi4041848
5. Hart, A., Heaver, B.: Evaluating resilience-based programs for schools using a systematic consultative review. J. Child Youth Dev. **1**(1), 23–53 (2013)
6. Lindley, P.: Practitioner resilience; building resilience in health visitor students for coping with adversity in practice. Resilience Forum Presentation (2013). bit.ly/1vFrVkR
7. Margalit, M., Idan, B.: Resilience and hope theory; an expanded paradigm for learning disabilities research. In: Resilience International Symposium, Talamus, vol. 22(1), pp. 58–64 (2004)
8. Nettles, S.M., Mucherach, W., Jones, D.S.: Understanding resilience. The role of social resources. J. Educ. Student Placed Risk **5**, 47–60 (2000)
9. Theron, L.: Critique of an intervention programme to promote resilience among learners with specific learning difficulties. S. Afr. J. Educ. **26**(2), 199–214
10. White, M.: Resilient Organization Culture. UNC Kenan Flagner Business School, UNC Executive Development (2013)
11. Masten, A.S., Best, K.M., Garmezy, N.: Resilience and development: contributions from the study of children who overcome adversity. Dev. Psychopathol. **2**, 425–444 (1990). https://doi.org/10.1017/S0954579400005812
12. Mayenna, S.B.: The concept of resilience revisited. Disasters **30**(4), 434–450 (2006). https://doi.org/10.1111/j.0361-3666.2006.00331.x
13. Donald, D., Lazarus, S., Lolwana, P.: Educational Psychology in Social Context, 2nd edn. Oxford University Press, Cape Town (2002)
14. Cook, P., Du Toit, L.: Overcoming adversity with children affected by HIV/AIDS in the indigenous South African cultural context. In: Ungar, M. (ed.) Handbook for Working with Children and Youth. Pathways to Resilience Across Cultures and Contexts. Sage Publications, California (2005). ISBN 0195780515
15. Friesen, B.J., Brennan, E.: Strengthening families and communities, system building for resilience. In: Ungar, M. (ed.) Handbook for Working with Children and Youth Pathways to Resilience Across Cultures and Contexts, pp. 295–312. Sage, California (2005)

# Benefits of Using Remote Labs in Intelligent Control Teaching

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**Abstract.** The use of remote and virtual labs in teaching and learning activities can be very useful in different high education courses, especially in engineering courses. This paper presents the use of a remote experiment in a laboratory work of Intelligent Control subject of an engineering course. A remote lab system can represent an important tool to be used in practical classes, complementing the experiments in the lab and contributing to the enhancement of the students' experimental skills. For this purposes, a remote setup was considered to provide the interaction with the remote lab through the Internet, where students can visualize the lab using a Web camera and observe data in real time from the remote system and download it. Different type of experiments can be accomplished using this setup. This work includes some preliminary results about the assessment of the use of the remote lab by students of an engineering subject. The results are encouraging to continue to use this kind of online experimentation resource for teaching activities in different areas of engineering courses.

**Keywords:** Remote laboratories · Intelligent control · Teaching
Online experimentation · Assessment

## 1 Introduction

In the era of the Internet of (Every)Thing, where the interconnection between things and people is promoted and supported, online experimentation represents a great opportunity to support teaching and learning activities in several contexts of higher education courses. In particular, resources like remote and virtual experiments can contribute to the improvement of teaching activities, to the extension of the laboratory activities and to motivate students to perform practical works, understanding the concepts and achieving experimental skills.

Teachers and higher education institutions should be committed with the use of online resources to provide learning conditions that engage and address the current challenges of society [1]. Thus, it is very significant to make all the efforts to provide students with high quality learning experiences, by taking advantage of different


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technological supports, interfaces and resources, namely of online experiments based on remote and virtual labs [2].

In this context, the assessment of this kind of resources, involving teachers and students, is very important to consolidate and improve their quality. Therefore, the students' opinion is fundamental to understand their perspectives about learning methodologies supported by online experimentation, to find effective ways to call their attention for the benefits of this approach and to make successive improvements in order to reinforce the use of these resources in a valuable manner.

This paper describes and evaluates the use of a remote laboratory in a topic of intelligent control of an Electrical Engineering M.Sc. course.

## 2 Intelligent Control Subject

Automatic control has become an important field in almost every engineering subject. Over the years, the control teaching/learning approaches have become more motivating and interactive with the use of virtual/remote laboratories [3–6].

The resource presented here was considered in the subject "Intelligent Control" of the 4$^{th}$ year (1$^{st}$ semester) of the Electrical Engineering Master course at the New University of Lisbon, Portugal. This subject is intended to develop the students' skills on System Identification and Control techniques, using computational tools. It is focused on the design of control systems based on intelligent control techniques, such as artificial neural networks and fuzzy systems. In addition, linear systems identification and adaptive control are also studied.

The main goal is to study intelligent control techniques, both theoretically and applied. Starting by introducing concepts on linear dynamic systems identification and adaptive pole placement control, follows the use of artificial neural networks and fuzzy logics as a means to approximate nonlinear system dynamics. Therefore, the core of this subject is the development of neural and fuzzy controllers.

The program of the "Intelligent Control" subject includes the following topics:

- Linear Systems Identification: Problem; The identification process; Linear time invariant models; Parameter estimation: least squares; Model validation; RLS.
- Adaptive Control: Functional models; Pole placement.
- Artificial Neural Networks: The neuron; Activation functions; Feedforward neural networks; Approximation properties; Supervised training in multi-layer networks; Generalization and validation; Neural control architectures.
- Fuzzy Control: Fuzzy systems fundamentals; Fuzzification of variables; Inference with linguistic variables; Defuzzification of linguistic variables; Fuzzy control design.

The teaching activities comprise theoretical and practical classes, in which students have to carry out various practical works. Some of them involve solving theoretical-practical problems and carrying out simulation exercises and others include experimental tasks, namely through the interaction with lab systems.

In one of these practical works, students should interact with a remote lab, available online at the Laboratory of Industrial Informatics and Systems of the Department of Informatics Engineering of the University of Coimbra, to configure the experiment and obtain data from the real setup. Thus, they can identify, for example, the model of the system and to apply different controllers and evaluate their performance, comparing its behavior with the simulation results.

## 2.1 The Practical Work

The practical work, entitled "Fuzzy Control", is intended to use a strategy based on fuzzy logic for the purpose of designing a fuzzy Mamdani type PI controller. The process to control, whose dynamics is unknown, is located in Laboratory of Industrial Informatics and Systems of the Department of Informatics Engineering of the University of Coimbra. The communication with the process to be controlled is based on an Internet connection between the client, where the controller runs and the server, located remotely, and between the server and the process, through a wireless sensor network of type 802.15.4 (see Fig. 1).

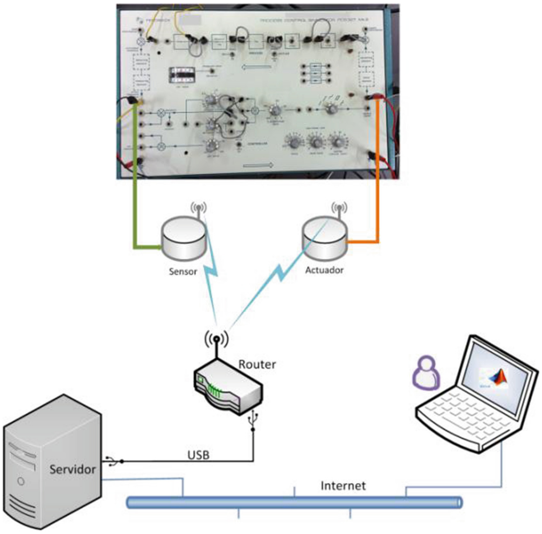


**Fig. 1.** Architecture of the communication model between the client and the remote setup.

This practical work comprises two main parts: Part A - Analysis and design of fuzzy controllers; Part B - Synthesis of a fuzzy controller for the remote system.

In Part A, students should analyze the system, to design fuzzy controllers considering a fuzzy structure with three fundamental modules, common to any fuzzy system, namely, the fuzzification, the inference engine and the defuzzification, and to determine the universe of discourse and fuzzy partitions associated with each linguistic variable.

Part B starts by training a neural network to approximate the nonlinear system dynamics subsequently tuning a fuzzy PI controller, using the neural model of the remote system, and performing the follow-up control of the remote system in real time, using a step reference signal. By collecting the output from the remote system, students can evaluate the performance of controllers.

## 3 The Remote Lab

As previously mentioned, the teaching of engineering can benefit from the presence of a strong practical component. Thus, the online experiments are, because of their availability, important enablers to a greater teaching quality, being essential to the remote lab.

One example of such an experiment is the nonlinear electrical system, namely the FEEDBACK PCS 327 (Fig. 2). It is of much utility, for instance to obtain a model of the system and to control it using different methodologies.

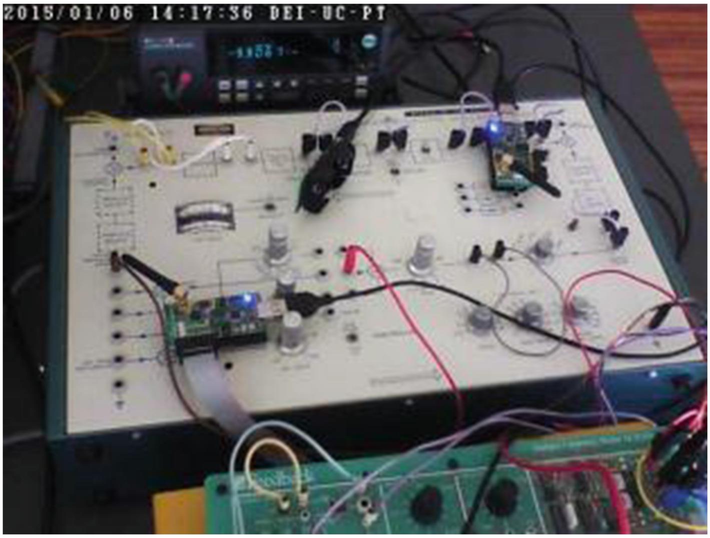


**Fig. 2.** Web camera image of the remote lab using a nonlinear electrical system for the online experiment.

It must be stressed that this system is remotely operable, allowing the user to change the inputs in an online interface and to observe the evolution and response of the system through images returned by a webcam located in the laboratory. Besides, it is also possible to test the experiment in a designed simulator, allowing to comparing the results.

This online experiment can be used for monitoring systems observing physics variables, systems identification, digital control of dynamic systems, networked control systems and distributed control systems, considering remote controllers in a shared communication network [7].

The remote monitoring and control of the systems can be implemented using a Wireless Sensor and Actuator Network (WSAN) within a distributed framework, where different sensors and actuators are spatially distributed and connected through nodes of the wireless network to a gateway, which provides the data to the main platform or to a local computer. The remote lab is based on a client-server architecture where the connection with the pilot plants is implemented through the WSAN [8].

## 4 Assessment Results

To assess students' perception and benefits regarding the use of the remote lab to perform a practical work, 34 students (in the first semester of the scholar year 2016/2017) were asked to complete a questionnaire.

A synthesis of the results of the questionnaire is presented in Table 1.

**Table 1.** Questionary results.

| # | Item | Median | Mode | Factor | Cronbach α |
|---|---|---|---|---|---|
| 1 | It was easy to perform this activity | 4 | 5 | Ease of use | 0.81 |
| 2 | I thought it was easy to analyze and project the diffuse controller | 4 | 4 | | |
| 3 | I became familiar quickly with using the remote system | 4 | 5 | | |
| 4 | I consider this activity as being very useful to train necessary skills in this course | 5 | 5 | Intrinsic value | 0.77 |
| 5 | I consider this activity of using a diffuse controller to control a remote system as very interesting | 4 | 4 | | |
| 6 | This activity was useful to learn how to project a diffuse controller | 4 | 5 | | |
| 7 | It is a good idea to use this remote system in the Intelligent Control course | 5 | 5 | Attitude | 0.90 |
| 8 | I feel it is very positive to use this remote system | 4 | 5 | | |
| 9 | I'm motivated to use other remote systems in the future | 4 | 4 | | |
| 10 | It is advisable to use the remote controller to learn about control | 4 | 4 | | |

The questionnaire aims at assessing three latent variables: Intrinsic Value [9], Ease of Use and Attitude [10].

Intrinsic Value represents how interesting and important students regard the activity with the fuzzy controller implementation. Ease of Use measures how easy to use students consider the controller to be. Attitude reflects how positive the students are towards using the remote controller to improve their skills. In order to estimate the reliability of the questionnaire, internal consistency was checked by computing the Cronbach's alpha. It is a measure of how well the items group in a factor.

As can be seen in Table 1, all of the values exceed 0.7, the accepted minimum for internal consistency. To determine how well a set of items load in the corresponding factor, Factor Analysis should be performed. This has not been done due to a relatively small sample size.

The median and mode for all items are 4 or 5, indicating that students consider the remote controller Easy to Use, Valuable and their Attitude is very positive towards using such a learning tool.

One limitation of this study is the small size of the sample (34 answers). More data should be gathered in order to establish this type of remote experiment as a motivational learning tool. Moreover, it would be important to combine the assessment of students' reaction with an assessment of students' performance in the related topics. However, in view of these preliminary results, the authors are encouraged to continue to use this kind of learning resources in their teaching activities.

## 5 Conclusion

This paper described the use of a remote lab in teaching and learning activities of a "Intelligent Control" subject and presented the analysis of the results of a questionnaire, which aimed at assessing three latent variables: Intrinsic Value, Ease of Use and Attitude.

The use of remote labs can represent an important tool in practical classes, complementing the laboratory experiments and contributing for the enhancement of the students' experimental skills. Therefore, a remote experimental setup was considered in this work, providing the interaction with the remote lab through the Web, where students can visualize the system using a Web camera and observe data in real time from the remote system and download it.

The preliminary results are encouraging to continue to use this kind of online experimentation resources for teaching activities in different areas of engineering courses and to enhance the students' learning process.

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## References


1. Garrison, D.R., Vaughan, N.D.: Blended Learning in Higher Education: Framework, Principles, and Guidelines. Wiley, San Francisco (2008)
2. Coito, F., Palma, L.B.: A remote laboratory environment for blended learning. In: 1st International Conference on PErvasive Technologies Related to Assistive Environments – PETRA 2008, Athens, Greece, pp. 226–229 (2008). https://doi.org/10.1145/1389586.1389667
3. Dormido, S.: Control learning: present and future. In: 15th IFAC World Congress, Barcelona, Spain (2002)
4. Kalúz, M., Cirka, L., Valo, R., Fikar, M.: ArPi lab: a low-cost remote laboratory for control education. In: 19th IFAC World Congress, Cape Town, South Africa, pp. 9057–9062 (2014)
5. Sáenz, J., Chacón, J., de La Torre, L., Visioli, A., Dormido, S.: Open and low-cost virtual and remote labs on control engineering. IEEE Access **3**, 805–814 (2015). https://doi.org/10.1109/ACCESS.2015.2442613
6. Heradio, R., de la Torre, L., Dormido, S.: Virtual and remote labs in control education: a survey. Annual Reviews in Control **42**, 1–10 (2016). https://doi.org/10.1016/j.arcontrol.2016.08.001. Elsevier
7. Cardoso, A., Sousa, V., Gil, P.: Demonstration of a remote control laboratory to support teaching in control engineering subjects. In: 11th IFAC Symposium on Advances in Control Education, Bratislava, Slovakia, pp. 226–229 (2016). https://doi.org/10.1016/j.ifacol.2016.07.181
8. Cardoso, A., Sousa, V., Leitão, J., Graveto, V., Gil, P.: Demonstration of identification and control of nonlinear systems using a remote lab. In: 3rd Experiment@ International Conference – exp.at'17, pp. 97–98 (2015). https://doi.org/10.1109/EXPAT.2015.7463224
9. Pintrich, P.R., De Groot, E.V.: Motivational and self-regulated learning components of classroom academic performance. J. Educ. Psychol. **82**, 3340 (1990)
10. Park, S.Y.: An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. Educ. Technol. Soc. **12**(3), 150162 (2009)

# Elements of Gamification in Virtual Learning Environments

## A Systematic Review

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**Abstract.** Information technologies have introduced several changes in teaching and learning environments. In this scenario, the gamification technique emerges as a promising approach, considering the impact on the students' motivation and appealing to their participation. This paper describes a systematic review addressing gamification in virtual learning environments (VLE), presenting an overview on how gamification has been applied in these scenarios. This review was based on papers published in highly scored journals in the field of computers in education. The papers were selected according to the gamification theme, and the content was analyzed and a state of the art built, according to the retrieved qualitative data. The results seem to reveal that there are significant gains derived from the adoption of gamification in VLE. However, some gains are not unanimous and it depends on how the elements are applied. This paper also suggests a basis for future work aiming at applying gamification in a VLE.

**Keywords:** Gamification · Virtual learning environments · Systematic review

## 1 Introduction

Nowadays there are many trends in Information and Communication Technologies (ICT) that lead us to a cultural change. Some authors suggest that we live in a digital culture. New generations were already born in this digital world, sometimes called digital natives, since they have spent their lives surrounded by computers, videogames, cell phones and have different ways to learn, and forcefully resist using the old method [1].

Traditional teaching and learning methods are challenging to digital natives, in the sense that the absence of technology undermines the students' motivation and emotional engagement [2].


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To overcome this gap, games emerge as an alternative way of combining technology and content in a playful result, that enhances emotional engagement. Gamification extends this concept by adopting gaming elements and mechanics in non-game contexts [2].

There are many efforts to apply gamification in education in order to increase the engagement of students. Usually, it is associated to a platform or a virtual learning environment to provide a common environment to students as well as a record of the students' progress. Nevertheless, there are issues that need to be addressed in order to apply gamification in learning environments. Not all elements are successfully applied and they should not be used blindly, just because they are trending. The elements should be carefully studied, understood and their application justified and implemented with the students' participation.

This paper presents a systematic review that was guided to identify and analyze gamification elements applied in virtual learning environments. This review also extracts results and considerations toward these applications. In this scenario, it is possible to observe the gamification elements in evidence, and present their outcomes when applied.

## 2 Theoretical Background

Deterding states that "gamification is the use of game design elements in non-game contexts" [3]. The elements of a game can be defined as a toolbox, where there are tools to perform different actions [4]. Then, game design elements wrap up these tools into a systematic and artistic design to achieve a predefined goal or objective. Finally, non-game contexts represent the use of games for other purposes than their normal expected use for entertainment [3]. So, this use must be intentional and responsible going beyond fun and entertainment.

Several researches recognize gamification as a mean to increase motivation and engagement [3]. Achieving user engagement reflects on more effort learning [5]. This can be useful in educational environments drawing attention towards a topic or subject, through untraditional approaches.

However, applying gamification in educational environments is not creating or playing a game. Instead, it should be considered as an incentive to change behavior within the learning outcomes and the pedagogical objectives, embedding game elements to foster engagement [6]. Moreover, if students are found to improve with such gamified approaches, the school and teaching processes should adapt and respond properly [7].

As a result, gamification is presented as an important alternative for scenarios targeting digital natives. It is possible to create engagement, obtaining numerous gains benefiting student's motivation on knowledge construction [8].

In parallel, Virtual Learning Environments integrate technology with education, making learning content and experiences available through the Internet [9]. However, some researchers suggest that the change in format is seldom motivating [10, 11].

In order to address this issue, there have been some efforts integrating VLE with gamification. This way supports educational theories, which can be implemented on the VLE, but also to proceed to engage students with gamification theories.

## 3 Methodology

The main research questions in this review are to assess which gamification elements are used in virtual learning environments and what is their contribution. For that, a through literature review was made.

The extraction from the literature of gamification elements usage in Virtual Learning Environments, started with a systematic literature review. This method can identify, evaluate and interpret in the available research those relevant to a particular phenomenon of interest [12, 13].

A systematic review involves several discrete activities in three main phases: planning, conducting and reporting the review [12].

The stages associated with planning are: (a) identification of the need for a review; and (b) development of a review protocol. The stages associated with conducting the review are: (a) identification of research; (b) selection of primary studies; (c) assess the quality of the study; (d) data extraction & monitoring; and (e) data synthesis. Finally, the reporting of the review stage is a single stage phase [12]. The phases in systematic review are presented below.

### 3.1 Planning the Review

This systematic review arises from the need to analyse existing papers focusing on VLE with gamification elements, to draw more general conclusions about the combination of these aspects.

### 3.2 Conducting the Review

**Identification of Research:** The source of this research was journals which fit into three selection criteria: high quality journal; learning as primary field; computers in education as secondary field. The journal search was conducted through CAPES platform, a Brazilian organization for scientific dissemination. This platform classifies journals in seven quality scores: A1 (Higher); A2; B1; B2; B3; B4; C (Lower). In this paper, the levels A1 and A2 were used as the quality parameter and learning as primary field.

**Table 1.** Selected journals to this review.

| ISSN | Journal | Short Name |
|---|---|---|
| 1539-3100 | International Journal of Distance Education Technologies | IJDET |
| 1055-8896 | Journal of Educational Multimedia and Hypermedia | JEMH |
| 1539-3585 | Journal of Information Technology Education | JITE |
| 1059-0145 | Journal of Science Education and Technology | JSET |
| 0360-1315 | Computers & Education | C&E |
| 2151-4755 | Creative Education | CE |
| 1695-288X | Revista Latinoamericana de Tecnología Educativa | RLTE |

Within the primary result set each journal was analyzed to identify the secondary field. The selected journals are presented in Table 1.

**Study Selection:** Within the selected journals, a search was conducted to select the studies which presented the word "gamification" in their content. Given the fact that gamification in educational environments is a recent theme, all years were covered in this search. The search returned 41 papers, structured by journal (Table 2).

**Table 2.** Total papers collected in primary search.

| Journal | Number of papers |
|---|---|
| Computers & Education | 31 |
| Creative Education | 7 |
| International Journal of Distance Education Technologies | 3 |
| Revista Latinoamericana de Tecnología Educativa | 0 |
| Journal of Educational Multimedia and Hypermedia | 0 |
| Journal of Information Technology Education | 0 |
| Journal of Science Education and Technology | 0 |

**Study quality assessment:** In addition to the general inclusion and exclusion criteria and the quality of primary studies, it is also necessary to look for the path to the answer to the main research question. The search criteria were very broad and many of the results were not useful to answer the research question.

Among the 41 papers, an additional step was performed to select the ones more useful to answer the research question. Papers that have no gamification applied in virtual learning environments have been removed from the results set (Table 3).

**Data extraction and monitoring:** This step defines all the information collected from papers to address this review question. This review proposes to identify trends in gamification applied to virtual learning environments. Therefore, to search for this evidence, the data extracted from papers is: (a) gamification elements; (b) their effects on the VLE.

**Data synthesis:** The final stage for conducting the review activity involves collating and summarizing the results of the included studies. To this review the synthesis is descriptive (non-quantitative), however it is possible to complement with a quantitative summary.

Werbach identifies a list of elements that can be used to operationalize gamification: achievements; avatars; badges; boss fights; collections; combat; content unlocking; gifting; leaderboards; levels; points; quests; social graphs; teams; and virtual goods [14]. This list was used as a starting point to analyze the selected papers. The results of the reporting the review activity are shown in the next sections.

**Table 3.** Selected papers

| Index | Title |
|---|---|
| P1 | Gamifying learning experiences: Practical implications and outcomes |
| P2 | Leaderboards in a virtual classroom: A test of stereotype threat and social comparison explanations for women's math performance |
| P3 | A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement and learning in an educational game |
| P4 | Gamification in assessment: Do points affect test performance? |
| P5 | Usage of a mobile social learning platform with virtual badges in a primary school |
| P6 | Digital badges in afterschool learning: Documenting the perspectives and experiences of students and educators |
| P7 | Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance |
| P8 | On the effectiveness of game-like and social approaches in learning: Comparing educational gaming, gamification & social networking |
| P9 | Engaging Asian students through game mechanics: Findings from two experiment studies |
| P10 | Cooperation begins: Encouraging critical thinking skills through cooperative reciprocity using a mobile learning game |
| P11 | Individualising gamification: An investigation of the impact of learning styles and personality traits on the efficacy of gamification using a prediction market |
| P12 | Open badges in online learning environments: Peer feedback and formative assessment as an engagement intervention for promoting agency |
| P13 | Motivation Strategy Using Gamification |
| P14 | Adaptive Ecosystem - Integrated Technology into the Curriculum |

## 4 Results

This stage identifies whether gamification elements are used in virtual learning environment, their focus and goals.

**Avatars:** A visual representation of a player's character. This element is used in most cases as an icon or figure that users are able to insert in order to represent themselves. Therefore, avatars in a game or digital world is a virtual representation of the player, it may take a 3D form.

P2 and P3 papers represents a player's avatars in a 3D form (Fig. 1a), while P1, P5, P8 and P11 only allow users to insert static images to represent themselves in the environment.


**Fig. 1.** (a) Avatar in a 3D form - P2; (b) Badges - P1.

**Badges:** A visual representation of a reward. Badges reflect the player's actions and contributions in an environment, for example, badges related to whether they were good commenters or questioners [15]. This element is presented in most of the papers: P1, P3, P5, P6, P7, P8, P9, P11, P12. Figure 1b shows this element in use.

This element is also connected with Collections element, representing a set of related badges in which participants are able to being recognized by their performance through this collection. Collection element was seen in P3, P5 and P11.

**Leaderboards:** A visual comparison of players' development or achievement. With this element, the progress of the user is public recognized and users are able to compare themselves with other colleagues [16].

This element is presented in papers: P1, P2, P3, P7, P8 and P11. Figure 2a shows this element in use.

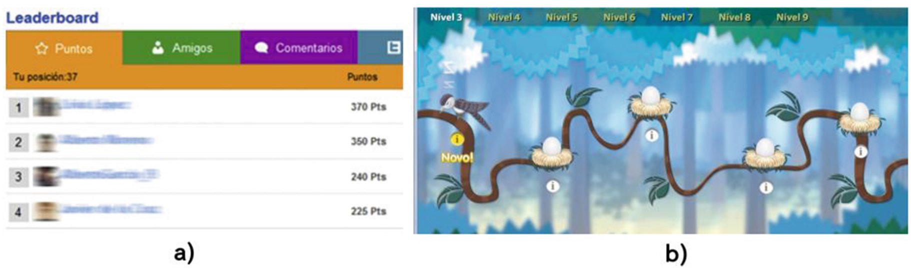


**Fig. 2.** (a) Leaderboard - P8; (b) Levels - P14.

**Levels:** Based on player expertise the game increases difficulty. This element also represents the sequence of activities that the users need to perform [17]. It can be represented in different forms, e.g. avatar evolution, progress bar, pathways.

This element is presented in papers P3, P5, P8, P9, P13 and P14. Figure 2b shows the level element applied to a pathway.

**Points:** Numeric value regarding players' performance on activities. A classic element of games points reveals a numeric value that represents user's progression in the game

[5]. This element is presented in papers: P1, P2, P3, P4, P5, P8, P9 and P14. Figure 3a shows this element in use in an assessment.


**Fig. 3.** (a) Points in a mathematic assessment – P4; (b) Users update in a social platform – P5.

**Social Graphs:** Social networks enabled with gamified activity. The users social integration is also a classic element of games. This element brings together gamification and social networking to create compelled socially-driven user experiences.

Many papers that allow social contact between users, e.g. chat. Yet, is explicitly presented in papers: P5, P8 and P10. Figure 3b shows this element in use.

**Teams:** Group of players collaborating to solve a question or an activity. This element encourages learners to work together to solve problems, to see others perspectives and cooperatively find creative and critical solutions. Teams element is presented in papers: P5, P8, P10 and P14. Figure 4 shows this element in use.


**Fig. 4.** Users collaborating in a 5-stage task (P10)

**Virtual Goods:** A reward with perceived value within the game. This element reward a user's action or behavior. This virtual good can be traded into benefits inside the environment. This element is presented in papers P7 and P11.

The Table 4 gathers the gamification elements used in each analyzed paper.

**Table 4.** Gamification elements in papers

| Elements \ Papers | P 1 | P 2 | P 3 | P 4 | P 5 | P 6 | P 7 | P 8 | P 9 | P 10 | P 11 | P 12 | P 13 | P 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Badges** | X | | X | | X | X | X | X | X | | X | X | | |
| **Points** | X | X | X | X | X | | | X | X | | | | | X |
| **Leaderboard** | X | X | X | | | | X | X | | | X | | | |
| **Level** | | | X | | X | | | X | X | | | | X | |
| **Avatar image** | X | | | | X | | | X | | | X | | | |
| **Avatar in 3D** | | X | X | | | | | | | | | | X | |
| **Teams** | | | | | X | | | X | | X | | | | X |
| **Social Graph** | | | | | X | | | X | | X | | | | |
| **Virtual Goods** | | | | | | | X | | | | X | | | |

## 5 Discussion

To complete the report & review stage of the systematic review, some conclusions were drawn from the results and presented below.

With insertion in most of the papers, badges are presented as a prominent gamification element, used primarily to reward the users' actions and contributions in an environment [15].

In most of the papers this element achieves good results, although problems may occur when badges are the only gamification element in the virtual environment, as it happens in P6 and P12. An isolated element may fail to develop the idea of gamification, depending on the way it was used and conveyed. Sometimes, it should be used with companion elements, for a more substantial experience [18].

Another issue is that badges should not be used as a single, explicit reward, risking to undermine the students' motivation by drawing the attention only to the reward. The environment has to maintain pedagogical objectives and badges must lead students to it [19].

Points are the second element with higher insertion among the analyzed papers and it was well accepted among them. From a theoretical perspective, points provide performance feedback for students especially when a task is succeeded.

Although the papers have shown that it is not clear whether students understand the objective of the points element, they can be seen as a piece of information about a task development, guiding the students' attention to the task, or can be seen as a reward for good performance, drawing the attention to the user [20].

When VLEs draw the attention to the user, the environment loses their pedagogical objective, limiting the objective to earning points, as seen in P4.

However, most of the papers has shown that it can be used to represent a user progression. Thus, merging points with levels may be considered as an important feedback mechanism, responding to an action or activity. Points and levels show good results when used as feedback progression providers.

Mainly connected to points or badges, leaderboards are another frequent element observed in papers. Leaderboards produce different opinions in virtual learning environments. Some authors, for instance P1 and P7, suggest that leaderboards guide users to an explicit social comparison leading to competition and undermining the students' performance and their cooperation [21]. While others suggest that it promotes motivation due to the public recognition progress in students [16].

Although it is unclear to suggest the viability of this element in learning environments, there are a higher number of papers that imply negative effects due its insertion.

Level element is also connected with the students' correct sequence of activities and it is also considered as an important element of game mechanics [17]. It can have several design layouts and different forms of representation, e.g. evolution of a badge or character, progress bar, unlock achievements, collectables.

As previously mentioned, when combined with points, this can produce good results, as seen in P3, P5, P8 and P9.

The avatar element is a virtual representation for a player. Many papers have used avatar as an image or user photo; yet, there are 3D avatars in some papers (P2, P3, P13). In most of the cases, avatars show progression or improvement due to users' actions or tasks. In this scenario the avatar increases the perceived value [2].

Although the analyzed papers do not suggest that this element improves engagement or motivation, it has students' approval from their insertion on traditional games and social networks, and this insertion may create users' engagement with the environment [2].

Finally, teams and social graph refer to social contact. Social networks and social media are pervasive nowadays. The authors in P8 suggest that these possibilities lead to positive results in virtual learning environments. This is mainly because virtual social contact is very common among digital natives.

The elements of teams and social graph make users feel part of a community and their actions contribute to more rich learning environments. Some authors point out that these elements are indispensable to reach the pedagogical dimensions and guarantee the quality of virtual environments [22].

## 6 Conclusion

Gamification in learning scenarios has become an increasing focus of interest for educational researchers for the effect on motivation among digital natives. The assumption is that combining learning environments with game elements and mechanics can contribute to engage learners and thus achieve more success.

In this scenario, our paper has conducted a systematic literature review in which the research goal was to see how the specialized literature uses gamification elements in virtual learning environments.

To meet this objective (goal?), a systematic review was conducted through the stages of planning, conducting and reporting the review. In the planning stage, we defined the research question which pervades our work. In conducting the review, we selected the data source from specialized literature, collected studies that were able to answer the research question and extract the information needed. Finally, in the reporting the review stage we discuss the results obtained from this research.

When evaluating the use of gamification elements there were predominantly inclusions of badges, points and leaderboards (PBLs). These elements were frequent in gamification approaches although we found that not all insertions presented positive outcomes. These elements must not divert the learner attention from pedagogical objectives.

Badges and points are presented as prominent elements depending on intended use. Furthermore, we have found that the most controversial element was leaderboards, that may harm students' motivation when promotes explicit competition.

We have also found that beyond the traditional PBL elements, there are many others that, although less frequent, are also able to present good results in VLEs. Together, these elements may promote motivation, collaborative learning, knowledge sharing, engagement among others.

The challenge is to design such environments to gather elements that promote learning outcomes and creatively fit these elements in pedagogical projects.

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## References

1. Prensky, M.: Digital natives, digital immigrants Part 1. On Horiz. **9**(5), 1–6 (2001)
2. Lee, H., Doh, Y.Y.: A study on the relationship between educational achievement and emotional engagement in a gameful interface for video lecture systems. In: ISUVR, pp. 34–37 (2012)
3. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining "Gamification." In: Proceedings of 15th International Academic MindTrek Conference, New York, pp. 9–15 (2011)
4. Brathwaite, B., Schreiber, I.: Challenges for Game Designers. Cengage Learning (2009)
5. Domínguez, A., Saenz-de-Navarrete, J., de-Marcos, L., Fernández-Sanz, L., Pagés, C., Martínez-Herráiz, J.-J.: Gamifying learning experiences: practical implications and outcomes. Comput. Educ. **63**, 380–392 (2013)
6. Shneiderman, B.: Designing for fun: how can we design user interfaces to be more fun? Interactions **11**(5), 48–50 (2004)
7. Erenli, K.: The impact of gamification - recommending education scenarios. Int. J. Emerg. Technol. Learn. (iJET) **8**(S1), 15–21 (2013)
8. Estevam, E.J.G., Kalinke, M.A.: Recursos Tecnológicos e Ensino de Estatística na Educação Básica: um cenário de pesquisas brasileiras. Rev. Bra. de Informática Na Educação, 21(02) (2013)
9. Sun, W., Zhang, W.: The research of collaborative e-learning system towards knowledge management. In: 2008 International Conference on Computer Science and Software Engineering, vol. 5, pp. 354–357 (2008)
10. Santana, M.A., dos Santos Neto, B.F., de Barros Costa, E.: Avaliando o Uso das Ferramentas Educacionais no Ambiente Virtual de Aprendizagem Moodle. Anais do SBIE **25**(1), 278–287 (2014)

11. Valente, L., Moreira, P., Dias, P.: Moodle: Moda, Mania ou Inovação na Formação? In: Moodle: estratégias pedagógicas e estudo de caso, pp. 35–54 (2009)
12. Kitchenham, B.: Procedures for Performing Systematic Reviews (NICTA Technical Report No. 0400011T.1). Keele University Technical Report (2013)
13. Linde, K., Willich, S.N.: How objective are systematic reviews? Differences between reviews on complementary medicine. J. R. Soc. Med. **96**, 17–22 (2003)
14. Werbach, K., Hunter, D.: For the win: how game thinking can revolutionize your business. Wharton Digital Press, Philadelphia (2012)
15. Bista, S.K., Nepal, S., Colineau, N., Paris, C.: Using gamification in an online community. In: 2012 8th International Conference on Collaborative Computing (CollaborateCom), pp. 611–618 (2012)
16. Mekler, E.D., Brühlmann, F., Opwis, K., Tuch, A.N.: Do points, levels and leaderboards harm intrinsic motivation? In: Proceedings of the First international conference on Gameful Design, New York, NY, pp. 66–73 (2013)
17. Gee, J.P.: What Video Games Have to Teach Us about Learning and Literacy, 2nd edn. Palgrave MacMillan Trade, Basingstoke (2007)
18. Juul, J.: Half-Real: Video Games Between Real Rules and Fictional Worlds. MIT Press, Cambridge (2011)
19. Abramovich, S., Higashi, R., Hunkele, T., Schunn, C., Shoop, R.: Achievement systems to boost achievement motivation. In: Presented at the Games Learning Society Conference (2011)
20. Attali, Y., Arieli-Attali, M.: Gamification in assessment: do points affect test performance? Comput. Educ. **83**, 57–63 (2015)
21. Orosz, G., Farkas, D., Roland-Lévy, C.: Are competition and extrinsic motivation reliable predictors of academic cheating? Front. Psychol. **4**, 87 (2013)
22. Hamid, A.A.: e-Learning: is it the “e” or the learning that matters? Internet High. Educ. **4**(3–4), 311–316 (2001)

# Evaluation and Outcomes Assessment

# Heuristics Discovered from Prototyping an Interactive System

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**Abstract.** Etymologically, the term "heuristics" is derived from a Greek term "heuriskein" which means "to discover". Heuristics refer to the specific "rules-of-thumb" discovered from knowledge or experience in order to solve a problem. In this study, a set of heuristics had been discovered by end-users while developing a series of prototypes of an interactive system called web-based test blueprint system. The heuristics are considered as minimum requirements that are deemed essential for a usable system.

This study suggests that the design process of an interactive system should cater to its technical domain as well as to its specialized domain. Thus, apart from proficiency in technical skills (e.g. user interface design), the designer of an interactive system must also demonstrate appropriate knowledge within the realm of the specialized domain (e.g. classroom assessment). Throughout the design process of the test blueprint, the underlying classroom assessment standards, theories, principles, and concepts had been highly considered while in consultation with the intended users and double experts. The end-users and the double experts have the strong knowledge and experience about the specialized domain and are also well-versed about the business processes, policies, standards, and organizational structure. The intended users from whom requirements are best captured should always be positioned at the center of the interactive system's development.

**Keywords:** Heuristics · Test blueprint
User-centered development · Prototypes

## 1 Introduction

User involvement in the design of an interactive system can be carried out easily through an organizational structure/protocol that promotes collaboration. The intended users of an interactive system are positioned at the centre of the design process. This means that users can either be (1) designers themselves or (2) involved as collaborators with the designer. In this study, the end users had been consulted and collaborated with the author who is the designer/developer of the web-based test blueprint system. This setup of peer collaboration effectively captures the actual requirements of the design of the said interactive system. As shown in Fig. 1, collaboration among a cohesive team of user representatives is evident that ultimately promotes the attainment of a shared


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goal and continuous improvement. Each user has a specific role to play, thus, actively engaged in the design of the interactive system.

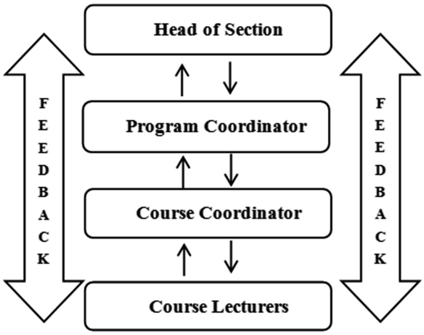


**Fig. 1.** Organizational structure and protocol (course level)

The interactive system under study is a test blueprint which is an effective test construction tool that ensures a more objective means of assessing students' learning experience or performance [1]. As shown in Fig. 1, test construction is performed in a two-way line of a collaborative process of communication among the users, namely: Course Lecturers, Course Coordinators, Program Coordinator, and Head of Section –all of whom are directly involved in the several stages of the interactive system design and implementation.

During the implementation of the test blueprint system, the preparation of the test blueprint is coordinated by a Course Coordinator working very closely with the Course Lecturers. All the Course Lecturers should agree to the test blueprint before its evaluation by the Program Coordinator. Once evaluated, the Head of Section finally approves it. Thereafter, the Course Coordinator and the Course Lecturers may write the test questions based on the approved test blueprint. After writing test questions, a rigorous moderation process will follow.

The author asserts that in an organization where peer collaboration is valued and supported, the best way to capture the requirements among themselves in the design of an interactive system is to utilize prototypes where they could interact among each other.

## 2 Conceptual Framework

There are many available models in systems design and development; however, the most suitable model when it comes to designing an interactive system is the Interaction Design Model (IDM) as shown in Fig. 2 which focuses on the intended users, otherwise known as the central design resource. IDM is a user-centered paradigm of system's development where all the stages are intertwined with each other that permit a series of iterations in order to address the needs of the users [1], which consists of four (4) interrelated stages, namely: (1) Establishing Requirements Stage which allows the designer, in consultation with the intended users, to constantly and systematically searches for pieces of evidence through multiple sources of information to form requirements; (2) Designing Alternatives Stage which is the core activity of designing a system i.e. coming up with a number of creative ideas that meet the users' requirements; (3) Prototyping Stage which is the most sensible way for users to evaluate interactive system's design through interaction with the prototypes; and (4) Evaluation Stage which uncovers and resolves any usability problems that users may encounter. Evaluation is an ongoing process that sustains the usability and acceptability levels of the system. If some requirements are missing or elements that may require improvement then these are fed back to be addressed in the preceding stage(s). Lastly, when an interactive system has been evaluated and found out to be an up-to-acceptable-level, then it has to be finally released for use among the intended users.

The specific stage which has been emphasized in this study is PROTOTYPING. Prototyping greatly relies on the insights and feedback of the intended users regarding the prototypes of the interactive system. Users' specific roles are interplayed in a collaborative manner resulting to a consensus of feedback that is useful in decision-making and in the design process. As an aftermath effect of user involvement, the intended users acquire a sense of ownership, acceptance without reservations, and active support over the interactive system.

Experts [2] claimed that "[…] prototypes are widely recognized to be a core means of exploring and expressing designs for interactive computer artifacts. It is a common practice to build prototypes in order to represent different states of an evolving design, and to explore options. Simulating a design through prototyping can reduce design risk without committing to the time and cost of full production."

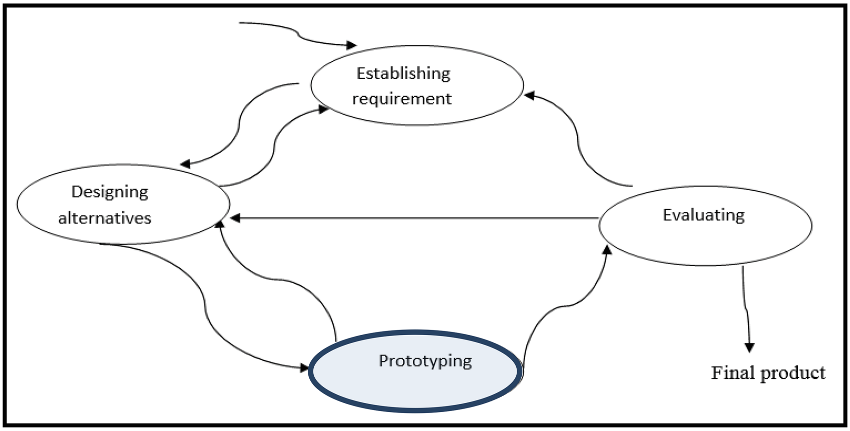


**Fig. 2.** Interaction Design Model [3]

Prototyping is highly intensive in the design process of interactive systems. This is the most sensible and collaborative way for users to improve the design of an interactive system through interaction with the prototype as it models and demonstrates the look-and-feel (behavior) of the interactive system. It allows designers to better understand users' real needs and preferences as it allows them to generate more ideas and articulate constructive feedback.

The author observed that there had been an improved collaboration and communication among the intended users. They shared their insights (thinking aloud) and were meticulous about the intricacies of the existing prototypes-at-hand, with the aim of playing an active part in the design of the interactive system. They were able to identify the potential pitfalls and patterns of possible flaws and foreseen risks that may cost failure during the design and implementation.

It is suggested to have a number of prototypes in order to allow users to select the best solution from the set of alternatives thereafter. Some designers are using prototypes to evaluate existing ideas. Users' rationale about their needs and requirements greatly influences the design of a more usable interactive system. There are many tools and techniques available for prototyping which ranges from 'paper-and-pencil' to 'more advanced technologies'. Prototypes do not necessarily produce fully-functional alternatives but rather are concrete representations that may envision and reflect the final product. It can be a low fidelity prototype or high fidelity prototype. In this study, two samples of prototypes of the test blueprint have been iteratively developed: (1) test blueprint using paper-and-pencil as the earlier version and (2) test blueprint using spreadsheets as the derivative version. The final product is a web-based test blueprint system.

## 3 Statement of the Problem

This study is motivated to show how to design an interactive system (e.g. web-based test blueprint system) using a user-centered model of development. Specifically, it aims to discover the appropriate heuristics from the series of test blueprint prototypes that are essential in the development of a usable interactive system.

## 4 Research Design: Methods and Procedures

This study made use of a descriptive research design with the following methods and procedures.

### 4.1 Literature Review

The author finds it very helpful to do a thorough review of related literature to establish content validity resulting to acceptable content validity index of the heuristics.

### 4.2 Focus Group Discussion (FGD)

The FGD session comprises of user representatives who could provide information, insights, feedback, and suggestions that are related to their respective role/tasks. It is a useful qualitative method of capturing specialized domain requirements that may assist the designer. The author of this study served as the moderator of the FGD.

### 4.3 Prototyping

A series of early versions called prototypes had been used in the development of a usable interactive system. Several iterations had been done in order to accommodate the intended users' needs and requirements.

## 5 Participants of the Study

There were double experts (n = 5) who participated in determining the content validity of the heuristics identified by the designer in consultation with the users. Double experts are those individuals who have multiple areas of expertise, including an area related to the specialized domain-under-study.

The number of participants (n = 10) during the Focus Group Discussion (FGD) session was within the range recommended by [4] which is six to twelve key informants. The FGD comprises of the Course Coordinators, Course Lecturers, Program Coordinators, and Head of Sections.

Moreover, there were ninety-three (93) intended users who actually interacted with the sample prototypes of the interactive system.

## 6 Data Analysis

The following tools were used to determine the content validity and reliability of the identified heuristics:

### 6.1 Content Validity Index (CVI)

The researcher made use of an empirical method called Content Validity Index (CVI) to analyze the feedback of the panel of double experts. The CVI determines the relevance of the heuristics. It is used to check whether or not the items adequately represent the specialized domain of content [5]. The double experts rated the items of heuristics based on their level of relevance, using the rating scale shown in Table 1.

**Table 1.** Relevance scale for Content Validity Indexing

| Rating | Description |
|---|---|
| 1 | Not relevant |
| 2 | Somewhat relevant |
| 3 | Quite relevant |
| 4 | Highly relevant |

The different key formulae used in Content Validity Indexing are listed in Table 2.

**Table 2.** Key formulae for content validity testing

| Entity | Formula |
|---|---|
| I-CVI (Item Content Validity Index) | I-CVI = No. of Agreement/No. of Raters |
| S-CVI/Ave (Subscale Content Validity Index/Average) | S-CVI/Ave = Average of I-CVI |
| S-CVI/UA (Subscale Content Validity Index/Universal Average) | S-CVI/UA = Total Agreement/No. of Items |
| No. of Agreement | The count of raters whose response is greater than or equal to 3, 3 being the marginal response<br>The count of No. of Agreed Items by the raters |
| Total Agreement | Total Agreement = Total number of items agreed by raters |

### 6.2 Cronbach's Alpha

The Cronbach's alpha, which is sometimes called the coefficient of reliability, is a renowned measure of internal consistency of a test or scale [6]. The Cronbach's alpha had been used to check the reliability of the items of heuristics identified in this study.

The rules of thumb corresponding to a Cronbach's alpha coefficient is shown in Table 3. Generally, it ranges from 0 to 1. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale.

**Table 3.** Cronbach's alpha coefficient [7]

| Cronbach's alpha coefficient | Description |
|---|---|
| 0.91–1.00 | Excellent |
| 0.81–0.90 | Good |
| 0.71–0.80 | Acceptable |
| 0.61–0.70 | Questionable |
| 0.50–0.60 | Poor |
| Less than 0.50 | Unacceptable |

## 7 Results and Findings

### 7.1 Prototypes

The author found out that prototypes used by the intended users can be "proofs-of-concept" geared to discover the appropriate heuristics derived from the sample prototypes through the use of Literature Review. It was revealed that the longer these prototypes have been used by users, the more brilliant ideas are generated by them which may help for the enhancement of the design of the interactive system. From the feedback received from users, not only the design and the technology had been improved but also the procedure for test construction preparation and examination approval of the institution. In other words, the logical and physical designs of the interactive system as well as the business process of the institution had been enhanced.

Below were the two samples of prototypes of the test blueprint that had been iteratively developed: (1) test blueprint using paper-and-pencil as the earlier version, shown in Fig. 3, and (2) test blueprint using spreadsheets as the derivative version, shown in Fig. 4.

**TABLE OF SPECIFICATIONS**
**E-Commerce for IT (ITBS2203)**
First Semester, AY 2011-2012

Course Code: ITBS2203 Course Title: E-Commerce for IT

| TOPICS TAUGHT/ CHAPTER TITLE | LEARNING OUTCOME NO. | INSTRUCTIONAL OBJECTIVES | BLOOM'S TAXONOMY COGNITIVE LEVEL | NO. OF HOURS SPENT | % OF TOTAL HOURS SPENT | NUMBER OF MARKS PER TOPIC | Allocated Marks Per Question/Cognitive Level |
|---|---|---|---|---|---|---|---|
| IA. Introduction to Electronic | 3, 4, 7, 10 | Explain the differences between E-Commerce and E-Business. | Comprehension | | | | 1 |

Course Code: ITBS2203 Course Title: E-Commerce for IT

| CHAPTER NO. | Knowledge | Comprehension | Application | Analysis | Synthesis | Evaluation | Total |
|---|---|---|---|---|---|---|---|
| Chapter 1T | | 9 | | 3 | | | 12 |
| Chapter 2T | | 2 | | 4 | | | 6 |
| Chapter 3T | 1 | 4 | | | | | 5 |
| Chapter 1P | | | 27 | | | | 27 |
| TOTAL | 1 (2%) | 15 (30%) | 27 (54%) | 7(14%) | 0 (0%) | 0 (0%) | 50(100%) |
| | 16 (32%) | | 34 (68%) | | | | |

Note: Synthesis and evaluation levels are tested in their course project/assignment.

**Fig. 3.** Paper-and-pencil prototype of the test blueprint

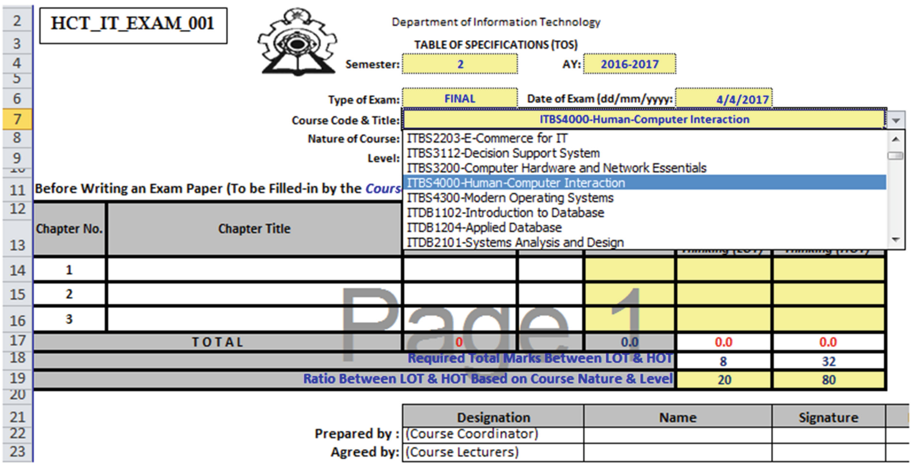


**Fig. 4.** Spreadsheet prototype of the test blueprint

## 7.2 Identified Heuristics Through Literature Review

The specialized domain in this particular study is Classroom Assessment in consonance to the interactive system called web-based test blueprint system. While the users were interacting with the prototypes of the interactive system, it was found out that the heuristics of a usable test blueprint had resulted to the following domain-specific heuristics as shown in Table 4, namely: (1) Content Validity, (2) Fairness and Comprehensiveness, (3) Accountability, and (4) Flexibility. Under each heuristic, there are sub-heuristics (n = 5) written in clear statements. The domain heuristics contain twenty (20) specific heuristics in total. These heuristics can be used during usability evaluation of the interactive system in the future. It was further claimed by the author that it is easier to frame the heuristics when supported by literature reviews.

**Table 4.** Domain heuristics (test blueprint heuristics)

| |
|---|
| *1. Content Validity* |
| 1.1 The Test Blueprint improves content validity of my students' exam [8] |
| 1.2 The Test Blueprint ensures that my students have achieved a specified standard of achievement or learning expectation at the end of their exam [9, 10] |
| 1.3 The Test Blueprint makes it easier for me to identify what types of exam are required based on the cognitive levels of LOT and HOT [11] |
| 1.4 The Test Blueprint helps me to construct a test which focuses on the key areas or topics which are weighted according to importance or significance [12–14] |
| 1.5 The Test Blueprint provides me a link between what is taught and what is tested both in content and in skills required [8] |
| *2. Fairness and Comprehensiveness* |
| 2.1 The Test Blueprint ensures that all the required course outcomes to be tested have been adequately covered [11, 14] |
| 2.2 The Test Blueprint ensures that there is a representative sample of questions from each chapter required to be covered [8] |
| 2.3 The Test Blueprint measures appropriate varied cognitive levels of my students which test different learning skills and types of exams [11, 14] |
| 2.4 The Test Blueprint creates a balance of testing between lower-ordered thinking skills and higher-ordered thinking skills that are appropriate to the level of my students [11, 14] |
| 2.5 The Test Blueprint produces an exam paper that does not discriminate the different types of learners [8] |
| *3. Accountability* |
| 3.1 The Test Blueprint helps me to create a degree of my own accountability [8] |
| 3.2 The Test Blueprint makes me confident to answer students' complaints or appeals at the end of the exam [12–14] |
| 3.3 The Test Blueprint can create quality exam resulting to a high GPA's credibility of my students [11, 14] |
| 3.4 The Test Blueprint is my effective exam paper preparation tool [12–14] |
| 3.5 The Test Blueprint is collaboratively prepared by a team (e.g. Course Coordinators with Course Lecturers) [9, 10] |

(*continued*)

**Table 4.** (*continued*)

| |
|---|
| *4. Flexibility* |
| 4.1 The Test Blueprint makes the teachers creative in writing an exam paper [8] |
| 4.2 The Test Blueprint preparation is a simple task after having been used to it [11] |
| 4.3 The Test Blueprint can prepare a common exam paper among multiple sections [9, 10] |
| 4.4 The Test Blueprint format can be modified according to the needs of the institution. [12–14] |
| 4.5 The Test Blueprint is following the existing exam procedures of the institution [8] |

### 7.3 Content Validity Index and Reliability of Heuristics

Subsequently, the heuristics listed in Table 4 were tested using Content Validity Index (CVI). The most acceptable value for I-CVI is 1 when there are 3–5 expert evaluators and the ideal value for S-CVI/Ave is 0.90 or higher [15].

As reported in Table 5, the heuristics are valid in terms of content according to the double experts because they all have mutual agreements on each item. All the items are relevant as shown by the S-CVI/Ave = 1, which exceeded the ideal value for S-CVI/Ave which is 0.90. Similarly, all the items are correlating well under each subscale as shown by the S-CVI/UA = 1.

**Table 5.** Summary of content validity testing results using Content Validity Index (CVI)

| Domain heuristics (test blueprint heuristics) | | | |
|---|---|---|---|
| Subscale | S-CVI/Ave | Total agreement | S-CVI/UA |
| 1. Content validity | 1 | 5 | 1 |
| 2. Fairness and comprehensiveness | 1 | 5 | 1 |
| 3. Accountability | 1 | 5 | 1 |
| 4. Flexibility | 1 | 5 | 1 |

On the other hand, the heuristics are deemed reliable as reported by the reliability coefficient of each item which is greater than 0.7. As shown in Table 6, the Cronbach's alpha coefficient is 0.76 which is considered acceptable and reliable.

**Table 6.** Reliability statistics

| Cronbach's alpha | Interpretation | No. of items |
|---|---|---|
| 0.76 | Acceptable | 20 |

### 7.4 Final Product (Web-Based Test Blueprint System)

Using the Interaction Design Model, the designer in consultation with the intended users was able to come up with the final product (web-based test blueprint) as shown in Fig. 5.

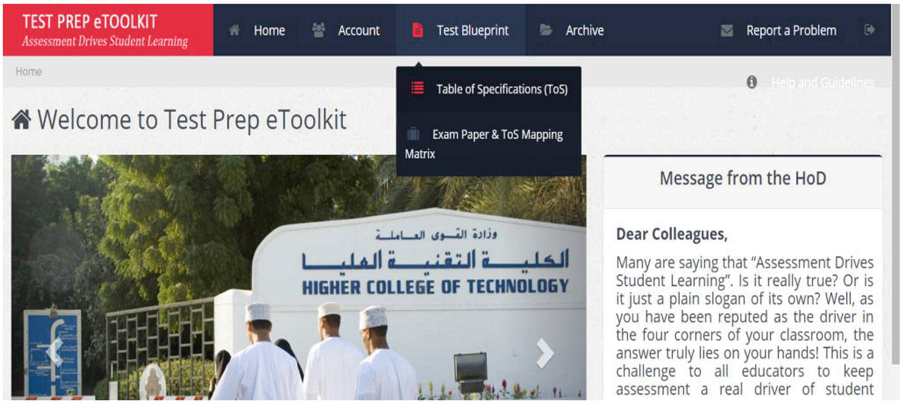


**Fig. 5.** Web-based test blueprint system home page

Figure 5 shows the homepage interface of the web-based test blueprint system. There are several menus added that make the system more usable. The heart of the system is found at the Test Blueprint menu which contains two (2) submenus, namely: Table of Specifications (TOS) and Exam Paper & TOS Mapping Matrix. The test blueprint comprises of the chapter number and chapter title, the percentage of chapter weight, the weighted mark, the actual allotted mark, and the level of difficulty (LOT/HOT ratio). On the other hand, the 'Exam Paper and TOS Mapping Matrix' shows how items should be mapped against the cognitive levels of the Bloom's Taxonomy of Learning. The exam paper should perfectly match with the approved TOS.

## 8 Conclusion and Recommendations

Based on the summary of findings of the study, (1) Heuristics can be derived while interacting with the series of prototypes. Such heuristics may serve as helpful benchmarks to evaluate the effective attributes of a usable interactive system. It is recommended, therefore, that the said heuristics should be utilized during the usability evaluation of the interactive system; (2) Prototypes are cost-effective and easy to use in generating more ideas from the intended users. It is recommended, therefore, that prototyping activities should always be included in the design process of any interactive system; (3) In developing interactive systems, there are two essential domains: technical domain (e.g. user interface design) and specialized domain (e.g. classroom assessment); (4) User involvement acquires a sense of ownership, support, and goodwill over the final product. The use of the user-centred approach to development called Interaction Design Model is recommended in designing interactive systems; and (5) The interactive system (Web-based Test Blueprint System) and the other prototypes presented in this study can be used as patterns for developing test blueprints by other educational institutions. The format of the test blueprint may vary depending on the needs and requirements of the educational institution.

## References


1. Singun, A.: Application-based test blueprint for a summative classroom assessment. In: Proceedings of the 10th International Management Conference “Challenges of Modern Management”, November 3-4, 2016, Bucharest, Romania (2016)
2. Houde, S., Hill, C.: What do prototypes prototype? In: Helander, M., Landauer, T., Prabhu, P. (eds.) Handbook of Human-Computer Interaction, 2nd edn. Elsevier Science B.V., Amsterdam (1997)
3. Rogers, Y., Sharp, H., Preece, J.: Interaction Design: Beyond Human-Computer Interaction, 3rd edn. Wiley, Hoboken (2011)
4. Maughan, P.D.: Focus groups. In: Dupuis, E.A. (eds.) Developing Web-Based Instruction: Planning, Designing, Managing, and Evaluating for Results. Facet Publishing, London (2003)
5. Polit, D.F., Beck, C.T.: Nursing Research: Principles and Methods, 7th edn. Lippincot, William, & Wilkins, Philadelphia (2004). ETS Assessment Training Institute, Portland, OR
6. Cronbach, L.: Test validation. In: Thorndike, R. (ed.) Educational Measurement, 2nd edn. pp. 443–507. American Council on Education, Washington, DC (1971)
7. George, D., Mallery, P.: SPSS for Windows Step by Step: A Simple Guide and Reference. 11.0 Update, 4th edn. Allyn & Bacon, Boston (2003)
8. American Educational Research Association: American Psychological Association, & National Council on Measurement in Education. Standards for educational and psychological testing. American Educational Research Association, Washington, DC (2014)
9. Mehrens, W.A., Lehmann, I.J.: Measurement and Evaluation in Education and Psychology, 3rd edn. Holt, Rinehart and Winston, New York (1991)
10. Nortar, C.E., Zuelke, D.C., Wilson, J.D., Yunker, B.D.: The table of specifications: insuring accountability in teacher made tests. J. Instr. Psychol. **31**, 115–129 (2004)
11. Linn, R.L., Gronlund, N.E.: Measurement and Assessment in Teaching. Merrill, Columbus, OH (2000)
12. Wolming, S., Wikstrom, C.: The concept of validity in theory and practice. Assess. Educ. Principles Policy Pract. **17**, 117–132 (2010)
13. Brookhart, S.M.: Assessment theory for college classrooms. New Dir. Teach. Learn. **2004** (100), 5–14 (2004). https://doi.org/10.1002/tl.165
14. Gronlund, N.E.: Assessment of Student Achievement, 8th edn. Pearson/Allyn & Bacon, Boston (2006)
15. Lynn, M.R.: Determination and quantification of content validity. Nurs. Res. **35**, 382–386 (1986)

# Plagiarism Detection in SQL Student Assignments

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**Abstract.** An original method for plagiarism detection in SQL student assignments has been proposed. The method is based on identifying so-called "SQL lexemes" - persistent elements of an SQL statement, and "SQL variables" - easily modifiable elements of SQL statements. Thus, any SQL statements can be replaced with a so-called token - sequence of SQL lexemes and SQL variables. Distance between SQL tokens can be calculated using such a well-known algorithm as Levenshtein Metric. Small values of Levenshtein distance between tokens detect such SQL statements that were built by modifications of others.

We also present first practical results of actual application of the algorithm, and discuss further developments of the method.

**Keywords:** e-Learning · Automatic evaluation · Automatic grading

## 1 Introduction

Learning by doing seems to be a common learning paradigm in teaching programming, databases and other computer science topics [2–7]. Normally, students are requested to implement practical assignments that can be seen as a practical application of obtained knowledge in the selected area. If we speak about databases, a student assignment is typically a definition of a database schema and of a number of queries by means of so-called SQL - standard language for defining and accessing databases that is supported by all relational Database Management Systems (DBMS) like Oracle, mySQL, Ingress, etc.

Checking and grading of students' assignments require a substantial amount of tedious work by teachers. Grading a particular assignment, the teacher must answer three main questions:

– was a required database functionality correctly implemented?
– is this implementation optimal?
– is this solution original or was done by cosmetic modifications of another assignment?

All the three issues above are reasonably complex; in this paper we concentrate on the third question - on automatic identification such assignments that were done by means of modification of other assignments.


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The problem of such identification deserves an individual investigation since:

– this is rather usual when students take an existing assignment and modify it by replacing original identifiers with other identifier (say, “student”→”pupil”, “student_name” →”pupil_name”, “lecture”→”class”, “teaching_book”→”lecture_notes”, etc.);
– standard methods of plagiarism detection does not work in such cases, since the methods are based on a detection of similarity of textual fragments, while SQL fragments look entirely different after the replacements as above.

## 2 Learning Management Environment

TU Graz TeachCenter is an innovative Learning Management System (LMS) that is used at Graz University of Technology, Austria for several years. Currently the system supports about 1500 individual courses and more than 20000 users. Normally, about 400 users are concurrently online. The system implements a number of different e-learning scenarios such as uploading individual assignments, uploading group projects, collaborative authoring, etc. One of the most popular components of Teach Center is a called “Programming Assignments”, and allows students to upload executable code as an assignment. The system automatically evaluates such course fragments and provides results of such evaluation.

The programming assignments are supposed to be uploaded into so-called “Group Lockers” (Fig. 1). “Group Locker” is a named memory space protected by a special key (Password). Anyone knowing the password may access and upload files into the group locker. Normally, students are requested to create lockers themselves. Names of the lockers are used to identify content. For example, lockers are often named “Group …”, “Project …” etc. The system supports different programming languages and can be set to work with SQL student assignments (Fig. 2).

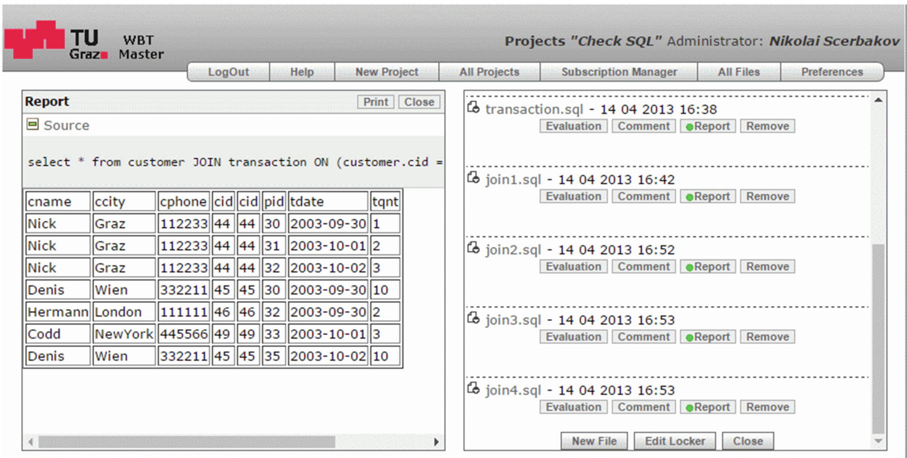


**Fig. 1.** Programming assignments.

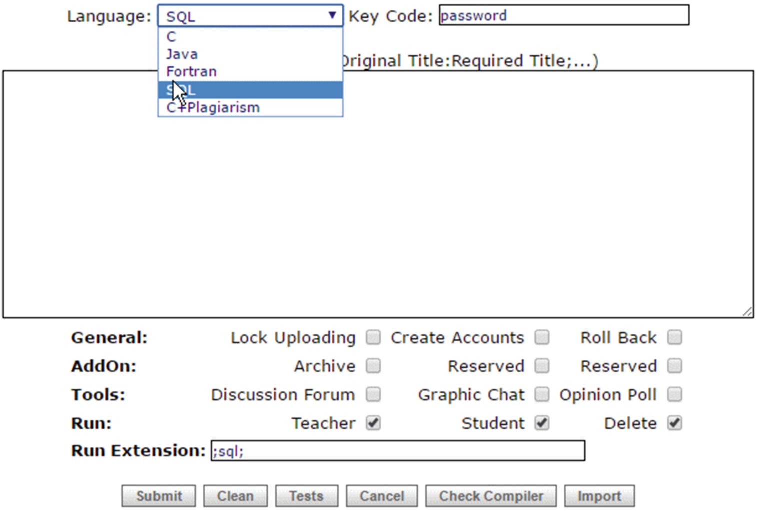


**Fig. 2.** Adjusting the system to evaluate SQL assignments

Typically, assignment requirements look as follows:

Please, develop a database application that consists of:

- Database schema of 4 relations;
- Two queries in terms of SQL. Each query should operate with 2-3 relations;
- Two SQL queries to illustrate the Join and set operations;
- Two SQL queries illustrating Group By and Having statements.

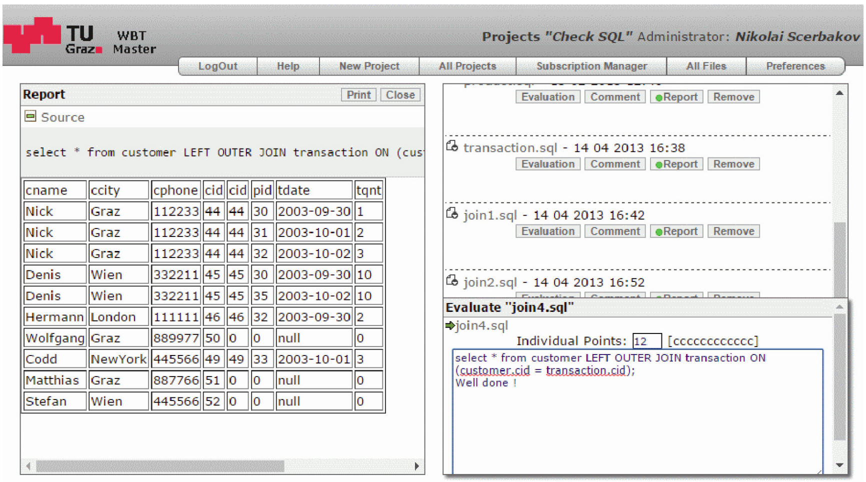


**Fig. 3.** Grading a student assignment

Students are supposed to upload local files having *.sql extension, and the system automatically evaluates the sources. The results are shown in the form of so-called “reports” (Fig. 3). Each report includes the source text and results of the automatic evaluation.

Grading of such programming assignments is a very tedious work. The teacher must look onto a source text and report that was produced as the file was evaluated, and answer the following questions:

- was the required database functionality correctly implemented?
- is this implementation optimal?
- is this solution original or was done by cosmetic modifications of another assignment?

Automatic evaluation of student files greatly facilitates checking correctness of the source texts. At the same time, standard methods of plagiarism detection does not work in the case of slightly modified SQL statements that may look entirely different after the simple replacements of titles for tables and attributes.

## 3 Plagiarism Detection

The method is based on identifying so-called “SQL lexemes” - persistent elements of an SQL statement, and “SQL variables” and “SQL constants” - easily modifiable elements of SQL statements. SQL variables and constants can be normalized, i.e. replaced with automatically generated titles in such a way that a certain normalized title replaces all occurrences of a particular SQL variable or constant. Thus, any SQL statements can be replaced with a so-called token - sequence of SQL lexemes and normalized titles.

For example, the four SQL statements can be converted into tokens as below:

```
CREATE TABLE `customer` (`cname` varchar(50),`ccity`
varchar(50),`cphone` int(11),`cid` int(11),
PRIMARY KEY  (`cid`));
```

**►CREATE TABLE #01 (#02 varchar(#N),#03 varchar(#N), #04 int(#N),#05 int(#N), PRIMARY KEY (#05));**

```
CREATE TABLE `product` (`pname` varchar(50),`pprice`
int(11) `pid` int(11) PRIMARY KEY  (`pid`));
```

**►CREATE TABLE #11 ( #12 varchar(#N),#13 int(#N) #14 int(#N) PRIMARY KEY (#14));**

```
CREATE TABLE `transaction`(`cid` int(11), `pid` int(11),
`tdate` date,`tqnt` int(11),PRIMARY KEY  (`cid`
`pid`,`tdate`));
```

**►CREATE TABLE #21 (#05 int(#N),#14 int(#N),#22 date, #23 int(#N), PRIMARY KEY (#05, #14, #22));**

```
SELECT cname, ccity, cphone FROM customer WHERE cid IN
 (SELECT cid FROM transaction Where pid IN
   (SELECT pid FROM product Where pname = 'VDU'));
```

**►SELECT #02,#03,#04 FROM #01 WHERE #05 IN (SELECT #05 FROM #21 WHERE #14 IN (SELECT #14 FROM #11 WHERE #12 = #S));**

Distance between SQL tokens can be calculated using such a well-known algorithm as Levenshtein Metric [1]. We calculate a Levenshtein distance [1] between two tokens as a minimum number of edit operations with normalized titles (insert, delete or replace) required to change one token into the other. Note, we consider any difference in SQL lexemes as a sign of absence of plagiarism. Small values of Levenshtein distance [1] between tokens detect such SQL statements that were built by modifications of others.

For example, the student assignment below is easily identified as an assignment suspicious for a plagiarism since tokens are simply identical, Levenshtein distance is equal to 0.

```
CREATE TABLE `patient` (`pat_name` varchar(30),`address`
varchar(60),`insurance` int(7), `pat_id` int(7)) PRIMARY
KEY  (`pat_id`));
```

**►CREATE TABLE #01 (#02 varchar(#N),#03 varchar(#N), #04 int(#N),#05 int(#N), PRIMARY KEY (#05));**

```
CREATE TABLE `medicine` (`med_name`
varchar(50),`med_length` int(4) `med_id` int(7) PRIMARY
KEY  (`med_id`));
```

**►CREATE TABLE #11 ( #12 varchar(#N), #13 int(#N), #14 int(#N) PRIMARY KEY (#14));**

```
CREATE TABLE `prescription`(`pat_id` int(7), `med_id`
int(7),  `pdate` date,`amount` int(11)),PRIMARY KEY
(`cid` `pid`,`tdate`));
```

**►CREATE TABLE #21 (#02 int(#N), #14 int(#N), #22 date, #23 int(#N)), PRIMARY KEY (#02, #14, #22));**

```
SELECT pat_name, address, insurance FROM patient WHERE
pat_id IN
  (SELECT pat_id FROM prescription Where med_id IN
  (SELECT med_id FROM medicine Where med_name ='Dysport'));
```

**►SELECT #02,#03,#04 FROM #01 WHERE #05 IN (SELECT #05 FROM #21 WHERE #14 IN (SELECT #14 FROM #11 WHERE #12 = #S));**

In more complex cases, the system can be adjusted by setting an upper limit for the value of the Levenshtein distance to identify suspicious assignments.

## 4 Conclusion

In this paper, we proposed a rather simple method for plagiarism detection in SQL student assignments. The method is based on converting students' assignments into so-called tokens, and calculating a Levenshtein distance between such tokens.

The system demonstrated rather good functionality. Thus, manually we could find out just 2–3 cases of plagiarism while grading 400 user assignments, the system identified 44 cases for the same amount of assignments. Of course, all the cases were checked manually, and students were asked to come for an additional interview. As a results, 18 cases we found out as really cases of plagiarism. Such a big number of plagiarisms can be explained by the fact that this was a first time we applied the system, and students were sure that that cases of plagiarism will not be detected manually. We also found that the system could be used as “early warning of plagiarism” for students, since substantial number of user assignments were identified as a plagiarism but students provided acceptable explanations of such similarity.

## References


1. Black, P.E. (ed.): Levenshtein distance. In: Dictionary of Algorithms and Data Structures [https://xlinux.nist.gov/dads/]. U.S. National Institute of Standards and Technology (2008). Accessed 4 May 2017
2. Macfadyen, L.P., Dawson, S.: Mining LMS data to develop an “early warning system” for educators: a proof of concept. Comput. Educ. **54**(2), 588–599 (2010)
3. Wu, J.H., Tennyson, R.D., Hsia, T.L.: A study of student satisfaction in a blended e-learning system environment. Comput. Educ. **55**(1), 155–164 (2010)
4. Dietinger, T., Maurer, H.: GENTLE – General Network Training and Learning Environment. In: Proceedings of ED-MEDIA98/ED-TELECOM 1998, Freiburg, pp. 274–280 (1998)
5. Ebner, M., Scerbakov, N., Maurer, H.: New features for e-learning in higher education for civil engineering. J. Univ. Sci. Technol. Learn. **1**(1), 93–106 (2016)
6. Scerbakov, A., Ebner, M., Scerbakov, N.: Using cloud services in a modern learning management system. J. Comput. Inf. Technol. **23**(1), 75–86 (2015)
7. Scerbakov, N.: TU Graz Teach-Center (2001). http://coronet-iicm.tugraz.at/wbtmaster/welcome.html. Accessed 13 Apr 2017

# Quantitative Evaluation of University Lecturing

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**Abstract.** In this paper we present a method for evaluating the quality of university lectures. The method is based on an analysis of students' behavior during working with online materials after visiting the classroom lectures or viewing prerecorded lectures. The students' behavior is monitored via analysis of Log files, and via special extensions of e-book readers and online movie viewers. All the data are recorded on a web site. The gathered data is analyzed to draw conclusions about the quality of lecturing.

**Keywords:** E-learning · Quantitative evaluation of lecturing
Quality of blended learning

## 1 Introduction

Quantities evaluation of quality of university courses is one of the most challenging tasks in quality control of higher education. Student evaluation of university courses can be subjective, unreliable or too general by considering the course as a whole.

The paper describes an attempt to automatically evaluate quality of university courses [3, 4] offered at Graz University of Technology.

The method is based on analyzing user behavior while users watch pre-recorded lectures and work through online e-books and scripts [3–5]. We introduce a number of templates of user behavior as combination of events. Typical events are correct answering a question, accessing a particular e-book fragment, watching a video fragment, etc. The events are automatically recorded as students work with the online course materials. Recorded data are analyzed to make a preliminary conclusion on the quality of the lecture materials [2].

This method is used as a more objective evaluation of university lectures, to complement student evaluation and rectify the minuses of student evaluations. The templates of user behavior are elaborated to render students' understanding of lecture materials and evaluate the complexity of lectures at an individual level. Most often, such evaluation zooms out and reflects students' perception of the course as a whole.


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## 2 E-Learning Environment

Blended learning is a main e-learning paradigm that is used in Technical University, Graz, Austria [3, 4]. Thus, all the courses have allocated classroom hours that are used for lecturing and other face-to-face teaching. Additionally, each course has an associated collection of online training materials available via the Internet. Such collection of materials is called an E-Learning course. E-Learning courses reside on a special Learning Management System called TeachCenter (Fig. 1). Currently the system serves about 2,000 courses and 20,000 individual users [7]. Normally a Teach Center course consists of announcements, curriculum description, library of courseware materials and a number of additional applications, such as online examination, uploading areas, collaborative authoring etc. [7]. We suppose that all courses are offered to students in a blended mode, i.e. a conventional classroom teaching is enhanced by means of utilizing e-learning technology.

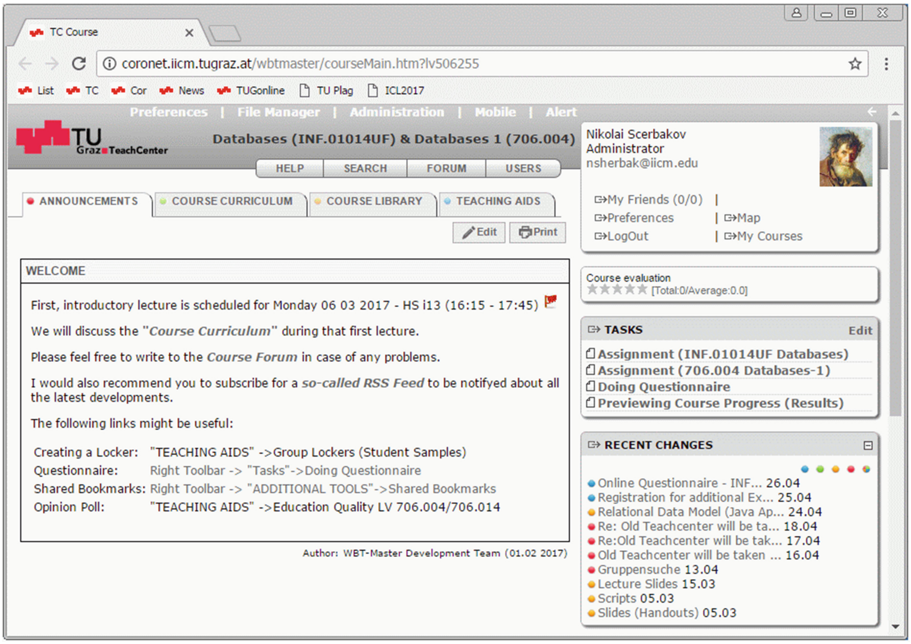


**Fig. 1.** E-learning course

A significant part of courseware materials available from such E-Learning course are pre-recorded classroom lectures. We suppose that all the lectures are accompanied with a so-called E-Book - a hierarchically structured collection of plain HTML documents and self-assessment questions. E-Book provides two types of access - sequential reading where users use buttons “Next” and “Prior”; and direct access via a table of content where any section, document and self-assessment question can accessed with one mouse click (Fig. 2).

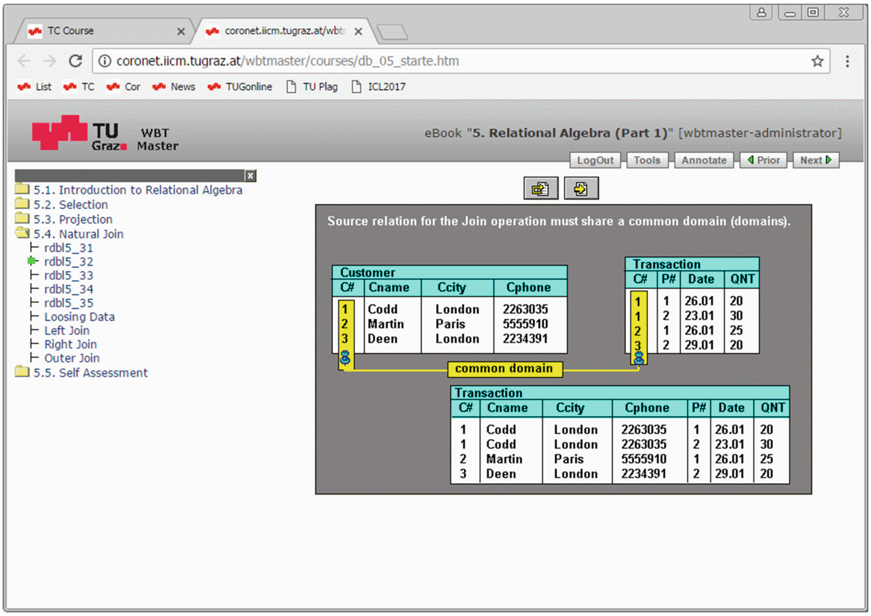


Fig. 2. E-book corresponding to one hour of classroom lecturing

## 3 Evaluation Method

Conventional university teaching is essentially based on classroom lecturing. In our case classroom lectures are recorded and offered to students via the Internet, i.e. in a distant mode [4–6]. Each lecture is also provided with online reading materials in the form of E-Book. To facilitate students' activity, there are a number of so-called online quizzes where students should answer a number of questions on the certain part of course content (Fig. 3). Positive results for online quizzes are a prerequisite for doing the final examination. Students are aware that they must do the online quiz on a particular fragment of the course; they also know that quiz questions are very similar to the self-assessment questions available in the E-Books. Students are advised to try self-assessment questions during the time slot between the lectures (i.e. after each lecture).

The quantitative evaluation is based on analyzing behavior of the students that work with E-Books and pre-recorded lectures.

We introduce five templates of behavior of students browsing an E-Learning course.

1. correct answering self-assessment questions without reading a corresponding part of the script or e-book;
2. wrong answering self-assessment questions and then reading a corresponding part of the script or e-book;
3. reading a fragment of the script or e-book and then answering self-assessment questions;

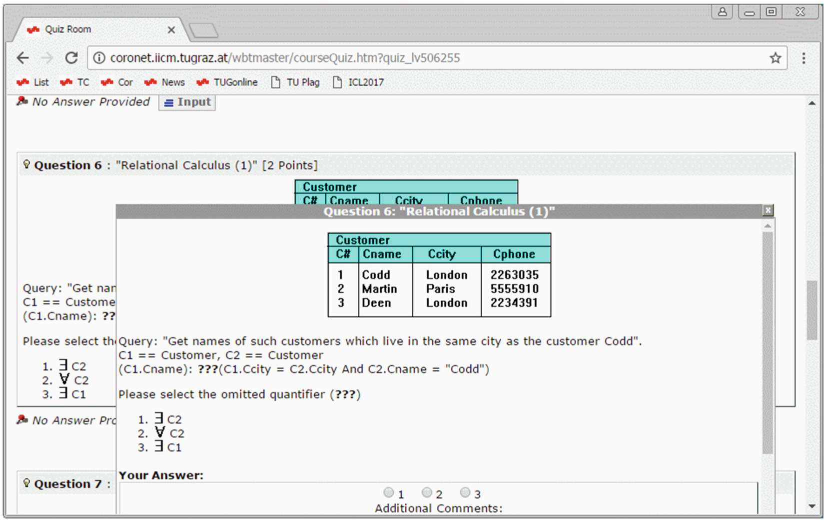

**Fig. 3.** Online quiz

4. wrong answering self-assessment questions and then watching a relevant fragment of the pre-recorded lecture;
5. watching a fragment of the prerecorded lecture and then answering self-assessment questions.

We record number of the students that worked with the online materials using a particular template. Percent of students using each of the behavior templates has a clear quantitative nature and can be seen as a signature of the lecture quality in a three dimensional space:

1. a percentage of students that comprehended the content from the classroom lecturing;
2. a percentage of students that had a feeling that they comprehended the content from the classroom lecturing, and needed just a short clarification;
3. a percentage of students that had a feeling that they had not comprehended the content from the classroom lecturing, and needed a repetition of the material in another form (E-Book or pre-recorded lecture).

Thus, a lecture can be seen as a point in a three-dimensional cube that roughly evaluates the quality of the lecture. Obviously a big percentage of students that had comprehended the content directly from the classroom lecturing indicate a very good lecturing style or, sometimes, simplicity of the content. On the contrary, if students need additional materials to comprehend the content, it might indicate an insufficient quality of the lecturing, or high complexity of the material.

In such cases, if students experience problems with the self-assessment questions, they can choice between a pre-recorded lecture and an E-Book. Selection the lecture recordings indicates good lecturing style that students prefer to reading of the scripts.

On the contrary, big values for user behavior in accordance with the third template indicate that lecturing still has room for improvement.

Thus, each lecture gets a quantitative evaluation in the three dimensional space. If individual lectures of the course gets very different figures, than the evaluation should not be trusted and complexity of the material presented in different lectures is not even. On the contrary, if the figures are stable for all the lectures, they provide a solid basis for consideration and improvement of the course.

## 4 Data Gathering Procedure

The data was gathered automatically via Asynchronous JavaScript and XML (AJAX) architecture. We introduced a number of additional events and procedures that process the events. E-Book reader was extended with an additional Plug-in module in order to record an access to all individual documents and automatically defines a sequence of pages that correspond to one of previously defined templates. As soon as such template is identified, a special event is triggered and result is recorded including the username, time, and template. Situation with movies was a bit more complex. All movies that were selected for this case study are supposed to be uploaded to the YouTube website and further embedded into Teach Center courses via a special movie player based on YouTube API. There are a number of reasons for using this API:

- Most students nowadays are used to watching YouTube videos and therefore will not have any problems with the player and the focus will be only on the video and not on possible usability problems.
- Reusing a professionally implemented and heavily tested API allows to avoid technical difficulties at runtime and bugs and spare efforts for developing proprietary viewer.
- Last but not least, we found out that the YouTube API provides all the data that is needed for our purposes.

## 5 Conclusion

In this paper, we proposed a new method of quantitative evaluation of lecture materials based on monitoring and analyzing user behavior while users work with supplementary online materials. The method is based on:

- Introducing a number of user behavior templates that characterize a way in which users work with the online materials to learn the content.
- Implementing algorithmic processing of such templates for all users working with the online materials via special JavaScript procedures.
- Gathering the data and recording them on a website using HTTP requests and AJAX architecture.
- Analyzing the gathered data in order to visualize them and infer logical conclusions on the quality of lecturing materials.

Along with receiving quantitative evaluation of lectures, we have carried out an ordinary informal evaluation of the same lectures by students using a special "Opinion Poll" WEB application.

The experiment demonstrates a particular correlation between results obtained by means of the method described here, and results shown by the informal evaluation. At the same time, we noticed that for some topics evaluation results are considerably different. Thus, for some lectures automatic quality evaluation provided very good results when informal evaluation showed that students are not entirely satisfied with the lectures. From our perspective, correct answering self-assessment questions without using any other online materials may not depend on the quality of lecturing but on the personal knowledge of the topic that students may have gained from some other courses or previous study.

We decided that further development of the method will include a pre-test to illustrate initial knowledge from particular students on certain topics. Then considering automatic evaluation only of the lectures that correspond to topics where students initially fail.

## References

1. Macfadyen, L.P., Dawson, S.: Mining LMS data to develop an "early warning system" for educators: a proof of concept. Comput. Educ. **54**(2), 588–599 (2010)
2. Wu, J.H., Tennyson, R.D., Hsia, T.L.: A study of student satisfaction in a blended e-learning system environment. Comput. Educ. **55**(1), 155–164 (2010)
3. Dietinger, T., Maurer, H.: GENTLE – general network training and learning environment. In: Proceedings of ED-MEDIA 1998/ED-TELECOM 1998, Freiburg, pp. 274–280 (1998)
4. Ebner, M., Scerbakov, N., Maurer, H.: New features for eLearning in higher education for civil engineering. J. Univ. Sci. Technol. Learn. **1**(1), 93–106 (2006)
5. Schaffert, S.: Strategic Integration of Open Educational Resources in Higher Education. Objectives, Case Studies, and the Impact of Web 2.0 on Universities (2010)
6. Scerbakov, A., Ebner, M., Scerbakov, N.: Using cloud services in a modern learning management system. J. Comput. Inf. Technol. **23**(1), 75–86 (2015)
7. Scerbakov, N.: TU Graz Teach-Center (2001). http://coronet-iicm.tugraz.at/wbtmaster/welcome.html. Accessed 13 Apr 2017

# School Development by Evaluation

## Competences Individual Treatment to Ensure Final Degree

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**Abstract.** Successfully reaching the final degree is an essential topic in education at the Higher Technical College EUREGIO HTBLVA Ferlach. This aspect is measured by "school achievement" which represents the proportion between the young people who have been trained in the first years and the pupils who finally graduate. This figure is, however, in practice dependent on many different factors. Factors such as the class climate, school climate, but also the handling of diversity and language sensitivity play an important role in classroom. For the development of these factors, social learning and problem based learning was implemented by projects. The evaluation shows, that the class climate felt by the students is getting better and project based learning is implemented and accepted by pupils and teachers. The value of "school achievement" was varying between 70% and 100% during the last 10 years. As preconditions of the pupils arriving at the Higher Technical College are decisive factors, there are actions planned and set to support pupils especially during the first year. To move on further to Industry 4.0 students competences in Information Technology are evaluated and simulation as well as data management is integrated in lecturing.

**Keywords:** Evaluation · Vocational education and training college
School development

## 1 Introduction

The EUREGIO HTBLVA Ferlach is a Higher Technical College which provides engineering education in manufacturing systems engineering and in art and design. The education in manufacturing systems engineering offers three focuses: (i) weapon and security engineering, (ii) production engineering, and (iii) industrial design. The purpose of quality management for classroom development is to lead a higher percentage of pupils through the process of five years education and to ensure a successful ending by reaching the final degree. Therefore, the main processes of school development are supporting pupils to reach this goal. Hence, specific projects and actions have been tuned in. In order to promote the development of education, schools and teachers are supported by the implementation of projects such as IMST (Innovations make schools Top) projects by cooperating with University and Austrian government. These projects have


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the aim to improve lecturing by implementing and evaluating new methods in teaching. Key words such as competence orientation and individualization are indispensable in school context. According to the Federal Ministry competence-oriented teaching and individualization are very important pedagogical guidelines for teaching. With the changeover of the EUREGIO HTBLVA Ferlach to the competence-oriented curriculum, the first semi-standardized maturity and diploma examination took place in 2014/2015. However, dealing with individualization and competence orientation is a key issue not only for graduation but also specifically for the transition from the 8th to the 9th school year. Hence, evaluation is applied to support and check the process of development and to perform the outcome assessment. Nowadays, industry 4.0 is raising as a second goal for the improvement of student education. Therefore, evaluation results are used to further develop and strengthen educational goals in this term.

## 2 Approach

School development is, on the one hand, based on the commitment of individual leaders and the involved teachers and on the other hand on structured development of the organization. In the following, quality development is described as performed at the EURGIO HTBLVA Ferlach.

### 2.1 Quality Management at Higher Technical Colleges

To support evaluation at schools, the Austrian Federal Ministry installed quality management as a development and control tool for all Austrian VET's (vocational education and training college) in 2008, and for all other schools during the last years. For the VETs, evaluation tools are available in form of questionnaires as well as quality management meetings and conferences. In addition, a competence-oriented curricula and standardized maturity and diploma examination are installed. In the context of quality management, evaluation tools are applied on the level of pupils and teachers where each of them can outline their opinions for specific focal points. The questionnaires used for data collection are available on the QIBB homepage [1] (Quality Management in Vocational Schools). The planning of the evaluation determines whether additional current questions are integrated individually for each year or project. The availability of a rapid digital evaluation means that the QIBB platform provides an extensive basis for collecting data efficiently.

The EUREGIO HTBLVA Ferlach divides the quality management into six fields, namely (i) vision/mission of the college, (ii) successful final degree, (iii) TechGirls, (iv) training in practice, (v) international and national cooperation, and (vi) knowledge management [2].

- Vision/mission of the college: This part involves at the moment main subjects as public relations and facilities and equipment in laboratories and workshops.
- Successful final degree: This component focuses on the development of classroom work, especially on individual treatment in education, projects, school and class climate, and absences without leave.

- TechGirls: As a technical college, the portion of girls lies about 20%. Therefore, the goal of this key aspect is to provide information particularly to girls at the age from five to fourteen about technical professions and technical education. Here active cooperation with local elementary, primary, and secondary schools is maintained.
- Training in practice: This focus involves carrying out diploma theses, supporting competences for live, exercise and sports, and performing final exams.
- International and national cooperation: The strategic focus lies in this area on the cooperation with companies, but also educational institutions in Austria and in Europe.
- Knowledge management: This partition supports collaboration within the teachers and further development of lecturing itself by applying the quality management instrument “Individual Feedback” in classrooms as well as in the management level of the college.

To check and further develop these six main focuses at the EUREGIO HTBLVA Ferlach about 600 students are interviewed on three topics each year, and the teaching staff on five topics. In addition, teachers have the opportunity to receive individual feedback from their pupils through a feedback questionnaire.

During the last years three important terms gave distinction to school development in Higher Technical Colleges in Austria: orientation on competences, individualization, and project based learning.

### 2.2 Concept of Improvement in Lecturing

Enhancement of orientation on competences and individualization is mentioned as key processes in supporting scholars especially to complete the first year at a Higher Technical College (HTC) and finally to pass the final degree successfully. Therefore, there are papers published by the Federal Ministry that describe the meaning and the main focus of these terms and their implementation in lecturing [3, 4]. Additionally, the curriculum was further developed and implemented in 2011 [5], which concluded the first standardized final degree at the EUREGIO HTBLVA Ferlach in 2014. The concept of orientation on competences is built on four towers of strength: The basics is the definition of standards according to a competence model in the different subjects. These models are described by descriptors and are charged by examples for lecturing. The second part is the definition of the competence and learning orientated curricula with the definition of the setting in teaching and education. Based on these two columns, the praxis in lecturing and examining was adapted and improved [3]. The concept is concluding for the Higher Technical Colleges with a partly standardized final degree. In Austria final exams are standardized for the subjects Mathematics, German, and English. As the main purpose of a Higher Technical College (HTC) is the vocational training and each HTC provides different focuses, the technical subjects are handled differently. Therefore, the final exam in these subjects has to be organized at the college itself, but the time and questionnaire structure is given by standardization. Orientation on competences itself is defined for example by Prof. Neuweg [6]. He divides knowledge into two parts. The first one is inert knowledge which is the knowledge that can be repeated and is easy to check but it is not useful in application. The second one is implicit knowledge. It is difficult to examine but it can be applied for doing something. The aim is to connect both kinds of knowledge to ensure the technical background knowledge and the knowledge for application in engineering. Based on the PISA Study 2012 [7] the main competences besides handling Mathematics, German, and English, are competences in natural sciences, in problem solving, and in digital media. Problem solving competences are supported by including problem based learning [8] into everyday lecturing. One possibility to fulfil this demand is project lecturing. The main regulations and rules for applying this method in lecturing are described within the edict for project lecturing [9]. This method is one method that supports individualization in lecturing as demanded by Winkler-Rigler [4].

# 3 Implementation

## 3.1 Quality Management at the EUREGIO HTBLVA Ferlach

Based on the before described background the Higher Technical College EURGIO HTBLVA Ferlach started with evaluations in 2008. In the first years of the QIBB system, the number of evaluations was not high. It took some time to implement the evaluations into school management. Since 2012 evaluations have been performed structured and within the last three years a standard of evaluations was performed each year (see Fig. 1). To be able to react on different concerns and focuses, the questionaries' are adapted by additional questions. This ensures information about goals of the school that are not directly included in the proposed questionnaires.

| QIBB Evaluation Form | HT College Level | | | | | P. School Level | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Level Scholar** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** |
| Advancement/Individualization | ■ | ■ | ■ | | | ■ | ■ | ■ | |
| Class Climate | ■ | ■ | ■ | | | ■ | ■ | ■ | |
| Assessment of Performance | | ■ | | | | | ■ | | ■ |
| Screeninginstrument | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| Hands on Training | | | | ■ | ■ | | | ■ | ■ |
| Content Language Integrated Learning | | | ■ | ■ | ■ | | | | |
| Competences for Live and Exercise | | | | ■ | ■ | | | | |
| Schul Live | ■ | | | | | ■ | | | ■ |

**Fig. 1.** Evaluation planning on scholar level for the evaluation from 2014–2017. HT College: Higher Technical College, P. School: Professional School

The results are based on evaluations on the topics of school success, class climate, school climate, and competences at pupil level, individualization and competence orientation on pupils and teacher level. For each theme, the development from 2011 to 2017 is evaluated. Figure 2 shows the number of feedbacks versus the year of evaluation on the level of the pupils.

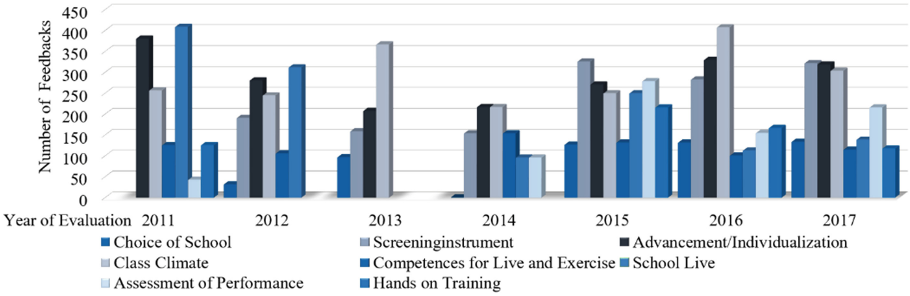


**Fig. 2.** Number of feedbacks per year from 2011 to 2017, scholar – level

In addition to the questionnaires based on QIBB the successful ending by reaching the final degree is monitored. This is done by the characteristic value of "school achievement". This value represents the proportion between the number of all pupils who start the second school year at the HTC EUREGIO HTBLVA Ferlach and the number of all pupils of the same classes who finish the final degree in time. This value is available for the period from 2005 till 2016.

### 3.2 Concept of Improvement in Lecturing

To ensure a good start into the HTC, the knowledge of the pupils who attend the first year at the HTC is checked by applying the so called "Diagnosis Check" which is a test that is proposed by the Federal Ministry. The used tasks are prepared and standardized for the beginning of the ninth school level. This check is performed within the first two school weeks in September/October each year. The results are used in addition to the observations of the teachers in class to apply an individual support for weaknesses of pupils. For several pupils the attendance at the HTC includes a change in living because the college is too far away from home to live out. Therefore, some of them have to change to a boarding school close to the HTC. This and the new situation in the new school leads to problems within the first school year. Since 2012 the lecture "Social and Personal Competences (SOPK)" is implemented, where social and personal requirements are addicted. This is thought to support the class climate and the school climate for the youth in addition to the personal engagement of the class teachers. Additionally a culture in project based learning has been developed during the evaluation period from 2012 to 2017. To support structured development in lecturing according to competence orientation and individualization IMST (Innovation Makes Schools Top) projects have been performed during the evaluation period yearly. These projects are supported by governmental funding and by scientific staff of pedagogic universities.

The purposes of the performed projects have been:

1. development of a concept for assessment of performance in individual teaching [10],
2. deepening and broadening of a concept for assessment of performance for individual teaching [11],
3. grasping Simulation [12],

4. capably validating simulation results [13],
5. preparation of documents for interdisciplinary lecturing in simulation, calculation and measuring [14], and
6. experiments in natural sciences [15].

In addition, the diploma thesis, which has to be performed by each student as part of the final exam, lasts over a period of six months. Here, groups of three to five students search on a specified theme often in cooperation with companies and supported by teachers. Each of these theses is a project on its own and with that partly involved in lecturing.

## 4 Evaluation and Discussion

In the following, evaluation results are presented and discussed based on the quantitative evaluation of the results of the used questionnaires in QIBB and on a SWOT analyses.

### 4.1 Quantitative Evaluation Based on QIBB

Figure 3 shows the development of school achievement from 2005 to 2016. The average value through the presented period is 88% (dark graph). The green graph shows the school achievement for the pupils of the Professional School and in blue one for the pupils of the Higher Technical College is displayed. The dark gray graph shows the value for both together. It is visible, that during the last four years the value of school achievement was decreasing. However, the values are fluctuating around the average value of about 20% up and down.

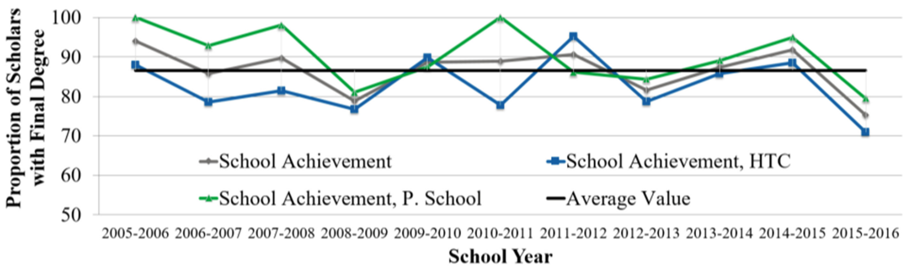


**Fig. 3.** School Achievement, development from 2006–2016.

At the beginning of the school year the first classes have to perform a check (diagnose check) in mathematics, German and English disciplines which provide intensive information about previous knowledge to the teacher. Based on these checks, about 50% of the pupils have weak mathematical knowledge and about 70% have weak German and English knowledge when entering the HTC (see Fig. 4). Based on the "Diagnoses Check" results, it is planned to establish a specific lecture assessment at the beginning of the school year to stabilize especially the basic knowledge in mathematics because it is known, that teaching in the first year can make a significant contribution to the integration in school.

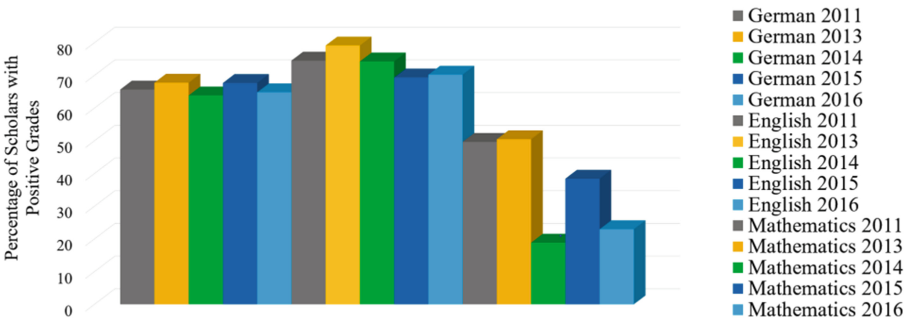


**Fig. 4.** Results of the "Diagnosis Check" at the beginning of the first school year. Development from 2011 to 2016.

In order to enlarge the "school achievement", teachers work not only on the improvement of lecturing in terms of individualization, but also on the classroom climate and school climate in terms of social skills. The interventions range from counseling on "violence at school" to the introduction of youth coaching as counseling at the school and the implementation of SOPK (social and personal competence) as lecture. The evaluations at school level in these areas show positive feedback on these interventions. Figure 5 shows the development of the class climate from 2007 to 2016.

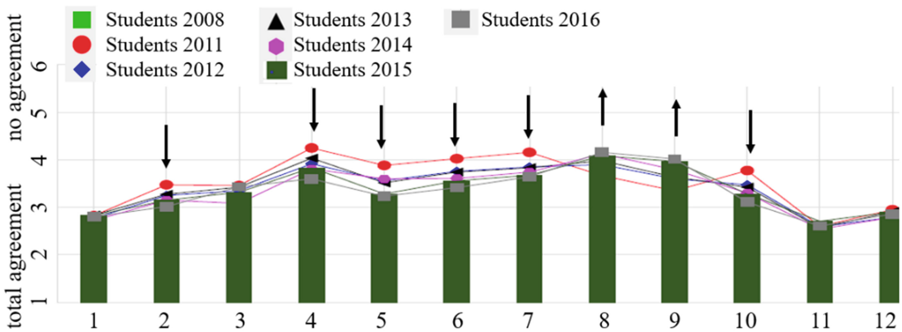


**Fig. 5.** Class room climate, development from 2007 to 2016. 1. I ask my classmates for help. 2. In our class we help and support each other. 3. Our teachers try to support and create a good atmosphere in class. 4. All students try to contribute to a good atmosphere in class. 5. In our class we can handle discussions and conflicts without violence. 6. In our class we interact in a fair way. 7. In our class we listen to each other although we might disagree. 8. In our class someone can become an outsider easily. 9. Some students of the class try to present themselves always in a good way. 10. In our class we have a good community. 11. I have a good friend/friends in our class. 12. I like going to this class.

The questionnaire contains the following questions:

1. I ask my classmates for help.
2. In our class we help and support each other.
3. Our teachers try to support and create a good atmosphere in class.
4. All students try to contribute to a good atmosphere in class.
5. In our class we can handle discussions and conflicts without violence.
6. In our class we interact in a fair way.
7. In our class we listen to each other although we might disagree.
8. In our class someone can become an outsider easily.
9. Some students of the class try to present themselves always in a good way.
10. In our class we have a good community.
11. I have a good friend/friends in our class.
12. I like going to this class.

The rating shows a scale from 1 to 6 where 1 means that the statement is right and 6 means the statement is wrong. The other values are distributed linearly in between. Hence, the decreasing values of the statements 2, 4, 5, 6, 7, 10 show a positive development in class climate and the increasing values for the statements 8 and 9, too.

### 4.2 Evaluation of Project Based Learning and Lecturing

Pupils and teachers have been asked to rate two statements as displayed in Fig. 6 to evaluate project based learning. The rating shows a scale from 1 to 6 where 1 means that the scholar agrees totally and 6 that the scholar does not agree at all.

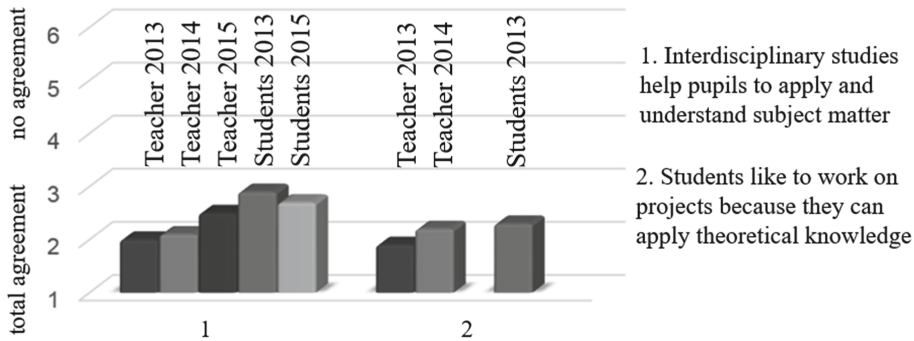


**Fig. 6.** Interdisciplinary education and project based learning

The other values are distributed linearly in between. Both, teachers and pupils give positive ratings. In addition, the results of a SWOT analysis is given in Fig. 7, where a sum up of the main aspects of project based learning from teachers view is given.

| **Strengths** | **Weaknesses** |
|---|---|
| Structured lessons help pupils and are demanded.<br>Lessons with projects concern and motivate pupils.<br>Ex-cathedra teaching is well known and supports structured lessons.<br>Pupils have fun practicing interactive methods.<br>Body-systems support learning.<br>Varying teaching methods helps to involve twitchy pupils.<br>Active learning supports sustainable knowledge.<br>Sense of responsibility is supported by problem-solving teaching. | Individualistic methods are not known. Therefore pupils have to be trained.<br>Individualistic methods need exact planning.<br>Teacher (and pupils) are not used to the output, hence efficiency is not felt.<br>Project based learning needs interaction between teachers which is hard to achieve.<br>Planning of projects is sometimes too optimistic.<br>Short chapters are easier to follow for students (depending on the age).<br>Feedback from students is often not serious. |
| **Opportunities** | **Threats** |
| Projects attract attention in classroom and school.<br>Projects are different therefore development is possible.<br>Documentation can be shared within teaching staff.<br>New experience is gained.<br>Interactive and cooperative learning enable individual deepening in subjects.<br>Interdisciplinary lectures support interconnectedness.<br>Federal ministry supports development of new methods in lecturing. | Interdisciplinary lecturing needs a strong strategy embedded in school.<br>Projects are usually innovative which increases the complexity in planning, additionally influenced by unforeseen happenings.<br>Strong interdisciplinary can lead to disorder.<br>Acoustic level is used to judge quality of lecturing.<br>Evaluation of individualistic and cooperative learning is difficult.<br>Strong reflection capacities are necessary for both, pupils and teacher. Therefore it is not so easy to assess the output. |

**Fig. 7.** SWOT analysis performed on teacher level

Another aspect in education is reaching of specific competences till passing the final degree for the expected work environment. To quantify the view of scholars the questionnaire "competences for life" is applied. The results of this evaluation are given in

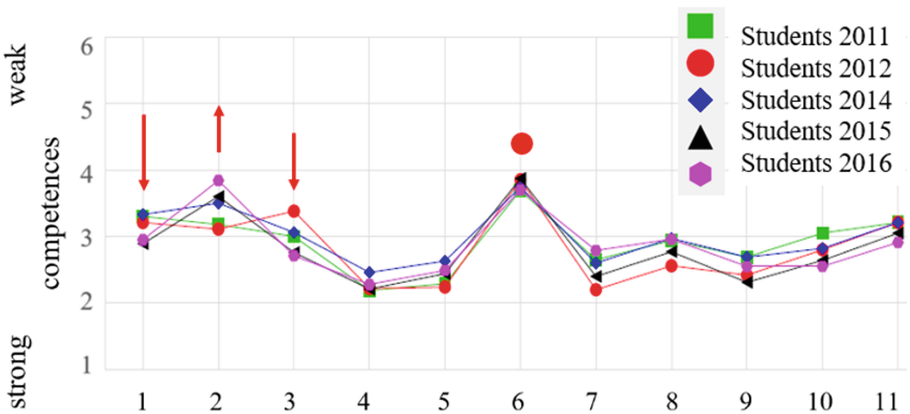


**Fig. 8.** Scholars evaluate, how strong they see their competences in the mentioned fields. 1: Languages, 2: Economy, 3: Mathematics/Natural Sciences, 4: Engineering Theory, 5: Engineering Practice, 6: IT, 7: Presentation Skills, 8: Communication Skills, 9: Teamwork, 10: Social Abilities, 11: Conflict Management

Fig. 8. Based on the point of view of the scholars, during the last years their competences in languages (Fig. 8, 1) have been getting better, as well as their competences in Mathematics and Natural Sciences (Fig. 8, 3). The competences in Information Technology (IT) are rated continuously with almost 4 during the evaluation. As IT is an important aspect in HTCs especially having regard to movement to Industry 4.0, here further inventions have to be performed. School management integrated already different online software applications for the teachers in order to support knowledge management. Additionally, the usage of clouds is forced on teachers and students level. Here the interventions already started 2012/2013 by IMST projects and diploma theses and simulation is implemented in construction and laboratory in specific lectures. As the results of the evaluation show, that there is a leak in usage of internet platforms and IT, this subject has to be worked on further in future.

## 5 Conclusions

The successful passing of the final degree is of main interest at a HTC, of pupils, teachers, school management, and parents. Hence, the concept of the work on increasing "school achievement" at the EUREGIO HTBLVA Ferlach is presented and the theoretical background is raised. The presented study is based on evaluations on the topics of school achievement, class climate, school climate, and competences at pupil level, individualization and competence orientation on pupil and teachers level. For each theme, the development from 2011 to 2017 is evaluated. In addition, actions taken by school management in these areas are given and analyzed based on the evaluation data. During the evaluation time range, several projects have been performed to develop and integrate project based learning at the HTC.

The evaluation data shows positive development in class climate as consequence of development during the first school year. Based on the performed "Diagnosis Check", support for the students is given especially in the first school year at the HTC. The data shows, that problem based learning included in teaching projects gets positive feedback from both, teachers and pupils. The evaluation of the point of view of the students of the fourth and fifth level in respect to their competences shows, that the self-assessment of the scholars has been increasing in matters of languages and Mathematics as well as in Natural Sciences. Additionally, it is obvious, that the self-assessment of students in Information Technology did not increase during the evaluation period.

Based on the presented results, further development will be performed in matters of (1) support of the pupils in the first school year by inducing a buddy-system and (2) projects to increase the self-assessment of students in Information Technology as background for the big move to Industry 4.0.

## References


1. Bundesministerium für Bildung: QIBB – initiative professional education. https://www.qibb.at/home.html
2. EUREGIO HTBLVA Ferlach: Quality Management (Qualitätsmanagement). http://www.htl-ferlach.at/de/unsere-schule/qualitaetsmanagement
3. Fritz, U.: Kompetenzorientiertes Unterrichten, Grundlagenpapier. Bundesministerium für Unterricht, Kunst und Kultur, Wien, p. 10 (2012)
4. Winkler-Rigler, G.: Individualisierung im Unterricht. Bm:ukk BT: ii7, Wien, p. 2 (2013)
5. Bundesministerium für Bildung und Frauen: Kompetenzorientierter Lehrplan. http://www.htl.at/fileadmin/content/Lehrplan/HTL_SV_2011_2012_2013/SV_Lehrplan_HL_Maschinenbau_2011.pdf
6. Neuweg, G.H.: Was ist Qualität in der Leistungsbeurteilung? Presentation at the PH Kärnten, Klagenfurt, 11 June 2011
7. Schwandtner, U., Schreiner, C.: PISA 2012. Leykam Buchverlagsgesellschaft mbH, Graz (2013)
8. Zumbach, J., Weber, A., Olsowski, G.: Problem-based learning. In: Zumbach, J., Weber, A., Olsowski, G. (eds.) Problembasiertes Lernen (256). h.e.p. Verlag, Bern (2007)
9. Auchmann, M., Bauer, L., Doppelbauer, A.H.: Grundsatzerlass zum Projektunterricht. bm:bwk, Wien (2001)
10. Grasser, M., Mayer, F., Gaber, V.: Development of a concept for assessment of performance for individualistic teaching. IUS, IMST, Klagenfurt (2011)
11. Grasser, M., Mayer, F., Gaber, V.: Deepening and broadening of a concept for assessment of performance for individualistic teaching. IUS, IMST, Klagenfurt (2011)
12. Grasser, M., Türk, C., Lindsberger, A., Mayer, F., Mörtlitz, P., Glas, G.: Grasping Simulation. IUS, IMST, Klagenfurt (2013)
13. Grasser, M., Mayer, F., Biller L.: Capably validating simulation results. IUS, IMST, Klagenfurt (2014)
14. Grasser, M., Mayer, F., Poklukar, F.: Preparation of documents for interdisciplinary lecturing in simulation, calculation and measuring. IUS, IMST, Klagenfurt (2015)
15. Grasser, M., Jesenko-Landerl, H.: Experiments in natural sciences. IUS, IMST, Klagenfurt (2015)

# Impact of Motivation, Gamification and Learning Style on Students' Interest in Maths Classes – A Study in 11 High School Grade

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**Abstract.** In the age of dynamic development of information and communication technologies, students get bored quickly and easily lose their interest and motivation for learning when the taught material gets presented in the traditional ways. The purpose of the following study is to determine the level of impact of gamification on the process of studying Mathematics, and on the emotional condition of students with certain motivation and learning styles. The results of the study show that the evaluation and implementation of the gamification, achieved with the usage of Kahoot! in the process of studying Mathematics, do not affect the academic achievements of students with low intrinsic motivation in terms of studying mathematics, however, positively affect their emotional state, stimulate their interest and promote active learning.

**Keywords:** Gamification · Students' motivation · Learning style
Mathematics education

## 1 Introduction

In today's modern, information-oriented and high-tech world, a great number of teachers experience serious difficulties in working and communicating with students. It is getting increasingly difficult to keep children's attention, to awaken their interest and to motivate them to study and actually learn. Undoubtedly, all this leads to: low activity in the course of the learning process; superficial and unsatisfactory academic results, and negative effects on the emotional state of the taught teenage students.

Information and communication technologies provide a wide range of opportunities to overcome some of the aforementioned problems. It is imperative that teachers in all disciplines should take advantage of these opportunities and adapt their teaching methods to the nowadays reality. A lot of the issues regarding low motivation, poor achievements and unpleasant emotions of students throughout the process of learning are largely related to math classes.

Generally, such may occur as Mathematics is an abstract discipline and the process of studying such a science is related to well-established teaching methods that are hard to get reformed. It is interesting to understand how new trends in education can be


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embedded in one of the most conservative sciences. An example of a modern teaching method that can be used in any sphere of human activity, and is applicable to each age group is gamification. According to Kapp [9]: "Gamification is using game – based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems." The aim of this study is to determine the impact of gamification on the process of studying mathematics, and on the emotional state of the students involved, who have certain motivation and learning styles.

The following stages, methods and instruments are exploited so that the goal of the study could be achieved:

1. Launch of a study among 11-th grade students at a language high school. Formation of an experimental group of students whose math training and evaluation gets assisted by gamification, realized in Kahoot's! environment and the formation of a control group.
2. Inquiry into the use of information and communication technologies (ICT) in the process of teaching Mathematics.
3. Determination of the motivation of students to study Mathematics with the help of Shawn M. Glynn's Science Motivation Questionnaire II.
4. Determination of the Learning Styles using the Multiple Intelligences Survey, created by Walter McKenzie.
5. Creation of didactic tests on "Trigonometric functions of general angles", and conducting a quiz. The experimental group conducts the aforementioned quiz in Kahoot's! environment, and the control group uses a PowerPoint presentation for that purpose.
6. Comparison and analysis of the achievements of the involved students in both of the groups who are taught and evaluated using different approaches.
7. Comparison and analysis of the results of the created by Kahoot! inquiry into the emotional state of the students in both groups.

## 2 Review of Theory

### 2.1 Kahoot!

Kahoot! is a game-based, free educational platform for creating and sharing tests. The aim of the game for the participants is to collect points that are granted for giving a correct answer and being fast. The response time of each question is set by the particular test creator. The game is played in real time: students respond using a smartphone, a tablet, or a computer connected to the Internet. At the end of each question and quiz, the system generates a ranking of the participants. In gaming mode, the system uses a timer and intense music to further influence the emotional state of the players. Kahoot! is an excellent example of a means of gamification because it exploits game mechanics, game thinking, aesthetics and leads to consumer engagement, motivate action and promoting learning. The user interface is quite simple and makes it easy for anyone to enter the questions and their possible answers. It is important to note that the system allows embedding of images and video. It is also possible to insert mathematical symbols – a possibility which is not generally supported by many similar systems. All of this gives us a reason to assert that Kahoot! can be successfully integrated into math classes, and can increase the level of the learning process activity. The level of the students' activity in the learning process depends on many factors, one of which is their motivation.

### 2.2 Motivation

"Motivation is perhaps the indispensable element, needed for school success" [1]. It has a significant impact because motivation itself: "is a desire to do something" [2]; "factors that activate, direct, and sustain goal – directed behavior" [3]; "as a set of interrelated desires, goals, needs, values, and emotions that explain the initiation, direction, intensity, persistence, and quality of behavior" [4]. In Self-Determination Theory (SDT) Richard Ryan and Edward Deci review different types of motivation.

Depending on its causes and aims, which lead to activity, they distinguish two basic kinds: intrinsic and extrinsic motivation. Intrinsic motivation is "the inherent tendency to seek out novelty and challenges, to extend and exercise ones's capacities, to explore, and to learn" [5]. "Extrinsic motivation refers to the performance of an activity in order to attain some separable outcome and, thus, contrasts with intrinsic motivation, which refers to doing an activity for the inherent satisfaction of the activity itself" [5]. There are many types of motivation in the scientific literature that are influenced by various factors and relate to different spheres. In this study, we are interested in the motivation to learn. According to Brophy it is: "a student's tendency to find academic activities meaningful and worthwhile and to try to get the intended learning benefits from them" [6]. In a more concrete sense of the word - "motivation to learn science as an internal state that arouses, directs, and sustains science-learning behaviour" [7].

### 2.3 Learning Style

There exist more than 70 learning styles theories and models [12]. The most popular of them are the Myers-Briggs Type Indicator, the Kolb's Learning Styles, the Felder-Silverman Learning Styles Model, the Gardner's Multiple Intelligence etc.

The learning style reflects the way the information is perceived and processed. Depending on how a person processes the information, Howard Gardner distinguishes multiple intelligences (MI). He considers intelligence "as a bio psychological potential to process information that can be active in a cultural setting to solve problems or create products that are of value in a culture" [13]. In [12], based on the theory of the multiple intelligence, a methodology has been developed to determine the learning styles of an individual. The styles proposed are classified into seven main groups: Visual (spatial), Aural (auditory-musical), Verbal (linguistic), Physical (kinesthetic), Logical (mathematical), Social (interpersonal), Solitary (intrapersonal).

Walter McKenzie systematizes the different Intelligence in the Wheel of MI Domains [8]. The creator specifies: "It is not a test but an inventory of learner preferences. It is not offered as a definitive measurement of a static intelligence, but as a snapshot of how your students currently perceive their strengths in all nine intelligences." He groups the intelligences into domains: the interactive (consists of the verbal, interpersonal, and kinesthetic intelligences), analytic (consists of the musical, logical, and naturalist intelligences) and introspective (consists of the existential, intrapersonal and visual intelligences). He proposed an inventory that consists of 90 statements, divided by 10 into 9 sections, corresponding to the different intelligences. Students respond according to a 2-point scale: 0 - “No” and 1 - “Yes”.

## 3 Research Methodology

### 3.1 Description of Target Group

The study is conducted among 153 students from the 11th grade at a foreign language high school. At the school mathematics is not among the major profiling disciplines, and students have only 2 classes per week. An experimental group (EG) is formed, which includes 78 students, and the remaining 75 students form a control group (CG). The number of people surveyed at the different stages of the study is not the same because, at the time of testing, some students are absent from school. The training and evaluation of EG students is aided by gamification, implemented in Kahoot! environment, and CG – with the help of PowerPoint presentations. For the evaluation of the students’ achievements, a six-point scale is used - ranging from 2 (weak) to 6 (excellent). For the statistical data processing software package SPSS at a level of confidence $\alpha = 0.05$ is used.

### 3.2 Method, Procedure and Result of Pre-survey

Prior to conducting experimental training, a survey is conducted about the use of ICT in the process of teaching Mathematics. The study involves 127 students. The survey finds out that 55% of students never use ICT while self-preparing for the math classes. Mathematics is the school subject that least benefits from technology, compared to foreign languages classes in which there is the highest frequency of use - 59%. 62% of the respondents say they get prepared for each math lesson: with 39% of the students studying for up to 30 min. According to 53% of students, the knowledge gained during their mathematics classes could be practically used. 47% agree with “mathematics develops the ability for rational and logical thinking”.

The students involved do not show any self-initiative for self-usage of ICT for the purpose of studying Mathematics. The time they spend on self-preparing is not enough, but they understand the meaning and the benefits of studying mathematics.

### 3.3 Method, Procedure and Result of the Study of Motivation to Learn Mathematics

To determine the motivation of students to study mathematics, the adapted to mathematics Science Motivation Questionnaire II 2011 Glynn et al. [10] is used. The questionnaire consists of 25 statements, divided by 5 in 5 different scales: intrinsic motivation, self-efficacy, self-determination, motivation and career motivation. The surveyed respond on a 5-step scale from 0 - “Never” to 4 - “Always”. The study involves 93 students: 45 from EG and 48 from CG. The Cronbach's alpha coefficient is used to verify the reliability. The alpha coefficient of all 25 items are 0.966, suggesting that the items have high internal consistency. The reliabilities of the five scale are: intrinsic motivation (0.843), self-efficacy (0.906), self-determination (0.868), grade motivation (0.877) and career motivation (0.933). The results show there is no statistical difference between the two groups, regarding the all type of motivation. There is, though, a statistically significant difference regarding the different motivation types. The Friedman Test gives $p = 0.0000$, $\chi^2 = 71.643$, $df = 4$. The grade motivation (regarded as extrinsic motivation) is dominant for both of the groups, a self-determination (viewed as intrinsic motivation) is the least common kind of motivation (Tables 1 and 2).

**Table 1.** Kruskal-Wallis tests for distribution of types of motivation regarding variable group.

| Null hypothesis | Test | p |
|---|---|---|
| The distribution of Intrinsic motivation is the same across categories of Group | Independent-Samples Kruskal-Wallis Test | 0.859 |
| The distribution of Self-efficacy is the same across categories of Group | Independent-Samples Kruskal-Wallis Test | 0.963 |
| The distribution of Self-determination is the same across categories of Group | Independent-Samples Kruskal-Wallis Test | 0.874 |
| The distribution of Grade motivation is the same across categories of Group | Independent-Samples Kruskal-Wallis Test | 0.386 |
| The distribution of Career motivation is the same across categories of Group | Independent-Samples Kruskal-Wallis Test | 0.427 |

**Table 2.** Descriptive statistics of all type of motivation.

| | Intrinsic motivation | Self-efficacy | Self-determination | Grade motivation | Career motivation |
|---|---|---|---|---|---|
| Mean | 10.02 | 11.24 | 9.27 | 13.33 | 11.65 |
| Median | 10.00 | 13.00 | 10.00 | 14.00 | 12.00 |
| Mode | 12 | 14 | 12 | 18 | 20 |

The data shows that the surveyed students do not make the effort and do not spend much time preparing for their math classes, but still want to get high marks. They are more interested in their grades than in gaining new knowledge or fulfilling an internal need. When comparing the statements: "I put enough effort into learning science" and "It's important that I get A in science" with Wilcoxon Signed Ranks Test, the $p = 0.0000$, $z = -3.714$ gives us reason to reject the null hypothesis.

In order to effectively teach students with such character and attitude characteristics, it is necessary to organize a learning process which, on the one hand, creates interest, awakens curiosity and activates activity, and on the other hand- provides evaluation and approval of the efforts they make. Gamification of the learning process would be an appropriate teaching strategy in such a case.

### 3.4 Method, Procedure and Result of the Learning Style (LS) Study

In this study the Multiple Intelligences Survey [8] created by Walter McKenzie is used.

The study involves 36 students from EG and 30 students from CG. The results show that 10 students in both groups possess an analytical, 11 - an interactive and 52 - an introspective domain, and 6 of them possess more than one leading domain. The leading domain of the students involved is introspective, which is “by nature affective processes” [8]. Affective processes are “processes regulating emotional states and elicitation of emotional responses” [11]. We can assume that Kahoot! will positively affect the emotional state of the students. Walter McKenzie [8] suggests using virtual field trips, online forms and surveys and slideshows when using media in the intelligence training process included in the introspective domain. All this gives us enough reason to choose Kahoot! and a PowerPoint presentation as a means of implementing the learning process goal: Check of the students’ knowledge about “Trigonometric Functions of a general Angle”. We also study the relationship between the learning style and the achievements of students from both of the groups, who are taught and evaluated with the help of Kahoot! or a PowerPoint presentation. Due to the small number of cases of Analytic and Interactive Domains, an analysis of data using Independent Samples Man-Whitney U Test with significance level $\alpha = 0.05$ is implemented together in both of the groups - CG and EG, and separately for each of the groups. The results are presented on the Tables 3 and 4. We can summarize that the LS has not affected the achievements of the students taught and evaluated with both Kahoot! and PowerPoint presentations.

**Table 3.** Independent samples Man-Whitney U test for distribution of students’ achievements (variable grades) according to learning styles.

| Null hypothesis | Sig. in CG | Sig. in EG | Sig. in CG + EG |
|---|---|---|---|
| The distribution of Grades is the same across Analytic LS Domain | 0.391 > 0.05 (Exact Significance Test) | 0.371 > 0.05 (Exact Significance Test) | 0.879 > 0.05 |
| The distribution of Grades is the same across Interactive Styles Domain | 0.859 > 0.05 (Exact Significance Test) | 0.971 > 0.05 (Exact Significance Test) | 0.883 > 0.05 |
| The distribution of Grades is the same across Introspective LS Domain | 0.929 > 0.05 (Exact Significance Test) | 0.325 > 0.05 (Exact Significance Test is Applied) | 0.406 > 0,05 |

**Table 4.** Independent samples Man-Whitney U test for distribution of students’ achievements (variable grades) according to groups (control - CG and experimental - EG).

| Null hypothesis | Sig. for students with Analytic LS Domain | Sig. for students with Interactive LS Domain | Sig. for students with Introspective LS Domain |
|---|---|---|---|
| The distribution of Grades is the same (CG, EG) | 0.257 > 0.05 (Exact Significance Test) | 1.000 > 0.05 (Exact Significance Test) | 1.000 > 0.05 (Exact Significance Test) |

### 3.5 Method, Procedure and Result of Studying the Achievements of Students, Taught and Evaluated with the Help of Kahoot! or a MS PowerPoint

To determine the knowledge, skills and competencies of $11^{th}$ grade students on the topic "Trigonometric functions of a general angle", a didactical test is created.

The test consisting of 10 questions with elective answers is created. The tasks, included in the test, are borrowed from math textbooks and collections for the following grade, and are presented in a traditional way. The experimental group takes a quiz in Kahoot's environment and the control group - using a MS PowerPoint. It is important to note that the students in both groups have to take the same test and the response time does not differ. For each specific question - a fixed response time is set, which is controlled by Kahoot! in one of the cases, and in the other – the time is pre-set in the PowerPoint presentation. The learning platform uses a timer and intense music, and the presentation - a signal sound that reflects the end of the response time and the start of the next question.

Students in both groups register their responses by using different means: CG record their responses on a sheet of paper, and the students from EG respond using a mobile device. EG is taking the test in real time, which allows them to immediately get the correct answer, the answers the participants have given, and compare the results. This enables the teacher to identify the weaknesses and the missing components and to take steps to fix them. Another important difference used in both approaches is the racing element - the collection of points (which students are awarded for any correct answer and the shortest response time). Kahoot! applies game mechanics, which is not used by the PowerPoint presentation approach.

The study involves 58 students from EG, and 56 from CG. Independent-Samples Mann-Whitney U Null Hypothesis Test is applied: The distribution of variable Grade is the same across categories of variable Group (CG - control group and EG - experimental group). The result is $p = 0.114 > 0.05$, which gives us reason to accept the null hypothesis, i.e. - there is no difference between the Kahoot evaluation! regarding the EG, and the PowerPoint presentation regarding the CG. This result suggests the following conclusion: the Game mechanics (gathering points, computing, and ranking) used by Kahoot! does not affect the students' achievements.

### 3.6 Relation Between the Learning Style and the Achievements of Students, Evaluated Using Different Approaches

For the purposes of the study, we also conduct a written evaluation of the students in both groups in a traditional way: the students should write down the solutions, and describe them thoroughly, the tasks are work-alone, in absolute silence, and the time for solving is one class. The material covered by the test represents the topic "Trigonometric functions of a general angle" and the number of the tasks is 10.

We compare the achievements of the students who get evaluated in a traditional way to the ones who are evaluated with the help of Kahoot! or a MS PowerPoint presentation. In the control group, the two evaluations are valid for 59 students, and for the experimental group the two assessments are valid for 29 students. There is no statistically significant difference between the achievements of students from both of the groups. There is applied a nonparametric Related - Samples Wilcoxon Signed Rank Test with null hypothesis: “The median of the difference between grades obtained with a traditional test, and with using a Kahoot!/MS PowerPoint equals 0.”, and has a level of significance $\alpha = 0.05$. The result shows $p = 0.0000 < 0.05$, which gives us reason to reject the null hypothesis, and assume that the results from the two evaluations are different. This leads us to the thought that the Kahoot test! or the MS PowerPoint based test is not appropriate for final assessment. There are several reasons for that: the response time of each question is limited, there is no possibility of correcting the answers given, and the external factors affecting the performance, such as the sound effects and the elevated mood in the classroom have an impact on the level of the concentration there.

### 3.7 Method, Procedure and Result of the Inquiry, Created with Kahoot! for Assessing the Satisfaction Level Among the Participants

Kahoot! conducts a survey among the participants after each quiz. The questionnaire consists of 4 questions that can determine: five-star rating of test; promote learning; recommendation to try the test, and the emotional state of the students after taking a quiz. For the purposes of our study, we review and analyze the results of this survey by conducting an inquiry with both the EG and CG (questions and possible answers do not differ among the students in both groups). The study involves 58 students from EG, and 56 students from CG.

Regarding the question “How do you rate this kahoot/test?” students have the opportunity to evaluate the test using the five-star scale. The ratings, given by responders using software in the EG and presentation in the CG, statistically differ (EG: Median = 5.00; CG: Median = 4). An Independent-Samples Median Test is applied with a level of significance $\alpha = 0.05$. The result shows $p = 0.0000 < 0.05$, which gives us a reason to assume that the students from the EG rate the test higher than the CG students. The students from both groups give high rankings to the test, although the tasks are presented in a traditional way and are not different from the ones they have to solve on a daily basis during classes. They like the test because there is exploited an unusual and innovative test approach in correspondence with their introspective domain. All of this undoubtedly leads to the awakening of interest, increasing in the motivation levels and encouraging the activity of the students. The higher approval rate among the students in the EG results from the gamification of the learning process that is achieved through Kahoot!.

The emoji scale: thumbs up (yes) and thumbs down (no) is used to answer the question “Did you learn something?” The two groups of students respond affirmatively, they think they have learnt something. 75% of CG and 76% of EG declare answer “Yes”. There is no statistically significant difference between the opinions of the EG and CG (Chi-Square test - $\chi 2 = 0.0011$, $p = 0.915$, $df = 1$). It turns out that no matter what the used assessment approach is: Kahoot! or a MS PowerPoint innovative methods as a whole encourage learning.

The answer to the question “Did you recommend it?” is given with a 2-step emoji scale: thumbs up (yes) and down (no). The answers of the students in both groups show a statistically significant difference (Chi-Square test - $\chi2 = 8.828$, $p = .003$. $df = 1$). The data shows that the EG students recommend (95%) the test more strongly compared to the ones from the CG (75%). A test which consists of traditional mathematical tasks is strongly recommended by students with low intrinsic motivation. This result is achieved by assessing and evaluating students with the help of gamification in Kahoot! environment. This means that the use of gamification in the process of studying mathematics is a preferred and desired approach by the students.

For answering the question "Tell us how you feel?" we use a 3-degree rating scale with faces and "smileys". The data strongly points out that the students from the EG are in excellent mood after the math class (Chi-Square test - $\chi2 = 22.564$, $df = 2$, $p = 0.0000$, $df = 1$). They are filled with positive emotions, can feel a sense of inner satisfaction and happiness. (EG - 69% Positive, 29% - Neutral, 2% Negative vs. CG - 25% Positive, 66% Neutral, 9% Negative). The data shows an apathetic state among the students as they remain indifferent to the learning process. This gives us a reason to assert that the gamification of the process of studying mathematics positively affects the emotional state of the students involved.

## 4 Conclusions

The conducted study shows:

- The students involved have not used ICT during their self-preparation for math classes, and have not spent enough time studying mathematics before this research gets conducted;
- The students' interest in studying mathematics is only associated with receiving high marks, although they are aware of the importance of studying this discipline;
- The students involved possess an introspective domain;
- The style of learning does not affect the achievements of the students who are taught and evaluated with Kahoot! or by using a PowerPoint presentation;
- The Game mechanics used by Kahoot! does not affect the achievements of the Kahoot-trained students!, or the PowerPoint presentation – trained students;
- The Kahoot! or PowerPoint presentation-based approach is not suitable for conducting final assessment;
- The gamification of the learning process in the Kahoot environment! is a preferred and desirable student learning approach;
- The innovative approaches used for evaluating like: Kahoot! And MS PowerPoint, awaken students' interest, boost their activity and encourage learning as a whole;
- The application of gamification in a Kahoot environment! has a positive influence on the emotional state of the students involved in the mathematics course
- The use of Kahoot! or MS PowerPoint does not affect the achievements of the surveyed students who have low intrinsic motivation and introspective domain. These means are not appropriate for conducting final assessments; however, they still stimulate interest and promote learning. Kahoot! represents a preferred and recommended by the students platform for evaluation that positively affects their emotional state.

The modern teacher must “know” their students, i.e. to be aware of their degree of motivation and their style of learning in order to be able to assess what innovative methods and techniques to use in the course of work. With gamification, maximum engagement and activation of students with low motivation is achieved. It ensures an elevated, bright and joyful atmosphere in the classroom. It can put an end of the tedious and boring math classes. Learning is no longer a difficulty for children and it starts giving them pleasure. The creation of pleasant emotions spontaneously leads to the implementation of a purposeful educational activity. All this gives us a reason to affirm that the information and communication technologies have a place in the learning process and can also be embedded in math classes. The positively charged learning environment created by using gamification via Kahoot! is a prerequisite for stimulating the interest and the level of motivation of the students involved.

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## References

1. Elliot, A.J., Dweck, C.S., Yeager, D.S.: Handbook of Competence and Motivation: Theory and Application. Guilford Publications, New York (2017). ISBN 9781462529605
2. Kim, J.-H., Lee, C.-H.: Multi-objective evolutionary generation process for specific personalities of artificial creature. IEEE Comput. Intell. Mag. **3**(1), 43–53 (2008)
3. Nevid, J.S.: Essentials of Psychology: Concepts and Applications, 5th edn. Cengage Learning, Belmont (2016)
4. Wentzel, K.R., Miele, D.B.: Handbook of Motivation at School, 2nd edn. Routledge, New York (2016)
5. Ryan, R.M., Deci, E.L.: Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. Am. Psychol. **55**(1), 68–78 (2000)
6. Brophy, J.: Motivating Students to Learn. Lawrence Erlbaum Associates, Mahwah (2004)
7. Bryan, R., Glynn, S., Kittleson, J.: Motivation, achievement, and advanced placement intent of high school students learning science. Sci. Educ. **95**(6), 1049–1065 (2011)
8. McKenzie, W.: Multiple Intelligences and Instructional Technology, 2nd edn. International Society for Technology in Education, Eugene (2005)
9. Kapp, K.: The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education. Pfeiffer, New York (2012)
10. Glynn, S.M., Brickman, P., Armstrong, N., Taasoobshirazi, G.: Science motivation questionnaire II: validation with science majors and nonscience majors. J. Res. Sci. Teach. **48**(10), 1159–1176 (2011)
11. Bandura, A.: Self-efficacy. In: Ramachandran, V.S. (ed.) Encyclopedia of human behavior, vol. 4, pp. 71–81. Academic Press, New York (1994)
12. Coffield, F., Moseley, D., Hall, E., Ecclestone, K.: Should We be Using Learning Styles? What Research Has to Say to Practice. Learning and Skills Research Centre, London (2004)
13. Gardner, H.: Intelligence Reframed: Multiple Intelligences for the 21st Century. Basic Books, New York (1999)

# Using Formal Concept Analysis in the Evaluation Process

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**Abstract.** Formal Concept Analysis (FCA) is a framework of knowledge processing and knowledge representation based on order and lattice theory. FCA methods can be adopted successfully in numerous areas of pedagogical work. This paper focuses on methods that can help teachers in the evaluation process. When a teacher evaluates a test, the results of the students are presented in a student assessment table. We create a question skill table as well, which shows the learning skills needed to answer the questions of the test. Combining these matrices, we construct a formal context and using its concept lattice we can make a deeper analysis of the test results. The obtained concept lattice visualizes the knowledge hierarchy of the class and the teacher can immediately determine the knowledge level of the class and its members individually.

**Keywords:** Formal context · Formal concept · Student assessment table
Evaluation context

## 1 Introduction

Formal Concept Analysis (FCA) deals with the formalization of concepts and conceptual thinking. "Formal" refers to the fact that a rigid mathematical definition of the concept is given here which must be distinguished from the concepts of the human mind. This definition uses the observation that a concept can be identified by a pair of two sets: one of them is a collection of the objects belonging to the concept and the other is a set of the common attributes of the objects. The main purpose of FCA is to describe the concepts and concept hierarchies in mathematical terms. The theoretical background of FCA originated from applied lattice theory. The basic definitions of FCA were introduced by Rudolf Wille in the early 1980s in Darmstadt, Germany.

In the last three decades FCA has been successfully applied in many disciplines. It is not surprising that it proved to be useful in areas related to knowledge discovery and representation; there are efficient FCA-based methods in linguistics, information retrieval, data mining, and ontology engineering. Beside the fields mentioned there are various applications in psychology, psychiatry, biological and social sciences, civil engineering, and security analysis. Categories of different and wide-ranging applications and a detailed list of related papers can be found in [1], a comprehensive survey analyzing more than 350 papers published after 2011 and showing the current research trends and the extension possibilities in FCA.


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In this paper we give the basic definitions, introduce the main tools in FCA, and show how FCA can be applied in the field of education. Our work focuses on the evaluation of students, especially in mathematics, but the methods and results can easily be adopted to other subjects.

## 2 Formal Concept Analysis

In this section we introduce some elementary notions of FCA, for a detailed discussion refer to [2].

Let $G$ be a set of given objects, $M$ be a set of attributes and $I \subseteq G \times M$ be a relation between these two sets, where $(g, m) \in I$ means that the object $g$ has the attribute $m$. The triple $(G, M, I)$ is called a *formal context*, which is often represented by a cross-table: the cell in row $i$ and column $j$ contains a symbol x if the $i$-th object has the $j$-th attributes. Table 1 is an example of context from [3].

**Table 1.** Context of animals

| ANIMALS | preying | flying | bird | mammals |
|---|---|---|---|---|
| LION | x | | | x |
| FINCH | | x | x | |
| EAGLE | x | x | x | |
| HARE | | | | x |
| OSTRICH | | | x | |

If $A \subseteq G$, we denote by $A'$ the common attributes of the objects belonging to $A$:

$$A' = \{m \in M \mid (g, m) \in I,\ \forall g \in A\},$$

and similarly, if $B \subseteq M$ we denote by $B'$ the set of the objects which possesses all properties of $B$:

$$B' = \{g \in G | (g, m) \in I,\ \forall m \in B\}$$

The pair $(A, B)$ is called a *concept* of the context $(G, M, I)$, if $A \subseteq G, B \subseteq M,\ \ A' = B$ and $B' = A$ hold. The set $A$ is called the *extent* of the context and the set $B$ is called the *intent* of the concept. In other words, the extent of a concept contains all the objects that belong to the concept and its intent consists of all the attributes that the objects have in common. For example, the pair {(FINCH, EAGLE), (flying, bird)} form a concept of the context presented in Table 1. It is easy to see that the set $A \subseteq G$ is the extent of some context if and only if $A'' = A$. In addition, any meet of extents yields an extent again.

We define an ordering relation between the concepts of a given context as follows:

$$(A_1, B_1) \leq (A_2, B_2) \leftrightarrow A_1 \subseteq A_2.$$

With this relation the set of the concepts of a given context forms a complete lattice, in which all subsets have an infimum (greatest lower bound) and a supremum (least upper bound).

*Remark*. The strict mathematical foundation of concept lattices is based on Galois connections and closure operators. This is the reason why sometimes the concept lattice is referred as a Galois lattice or Galois graph.

An important advantage of FCA is that the elements of a concept lattice can be visualized by a line diagram that expresses the hierarchical order of the concepts. For example, Fig. 1 represents the line diagram for the concept lattice of the context in Table 1.

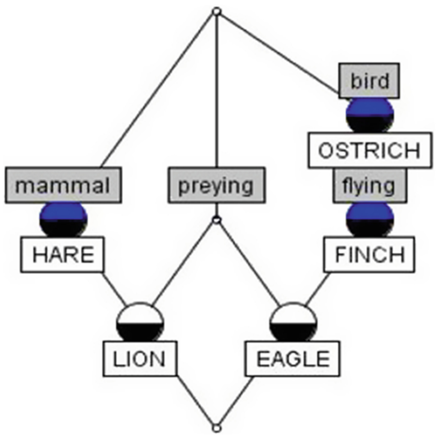


**Fig. 1.** Concept lattice of animals

The diagram is made by the software called Concept Explorer, which was developed for researchers and students working in the field of FCA. The diagram consists of circles, lines and the names of all the objects and attributes of the given context. The circles represent the concepts and the information of the context can be read from the line diagram by the following simple reading rule: An object *g* has an attribute *m* if and only if there is an upwards leading path from the circle named by "*g*" to the circle named by "*m*". Hence we recognize from the line diagram above that the FINCH has the attributes flying and bird. As a consequence of the reading rule we can easily read from the line diagram the extent and the intent of each concept by collecting all objects below and all attributes above the circle of the given concept. For example, the concept appearing in the middle of the lattice is {(LION, EAGLE), (preying)}. The top and bottom concepts in a concept lattice are special. The top concept has all formal objects in its extent and the bottom concept has all formal attributes in its intent.

# 3 Evaluation of Students Using FCA Tools

The introduced tools of FCA provide intuitive visualizations for a set of pedagogically relevant questions, for example in evaluation of students, designing exams and analyzing test results. The main purpose of evaluating is to determine the level of the knowledge and decide whether the teacher was successful in his/her work. The teacher must know the shortcomings, the weak points and the strengths of the students in order to be able to develop them efficiently, and a deeper analysis of tests can improve the teacher's classroom practices as well.

The most evident method to create a formal context in evaluating a test is making a student assessment table. It is a context in which the students correspond to objects and the problems/questions of the test are considered as attributes. The relation is given by $I = \{(g,m) \mid \text{student } g \text{ has solved problem } m\}$.

After creating the concept lattice of the context, the resulting lattice shows a hierarchical order of groups of students and test items as well. If we have only the list of results, we can calculate some statistical characteristics from the individual data, most frequently the mean or the median. The concept lattice provides much more information than a simple list of results. From the nodes of the lattice the individual results can be identified, but the lattice visualizes the knowledge structure of the whole class [4].

A more complex evaluation scheme was suggested in [5]. The authors elaborated a novel method that combines the student assessment table with the concepts obtained from the questions skill table. This table is a formal context containing the set of test questions as objects and the learning skills that are needed to answer the questions as attributes. The used learning skills were analytical, mental, numerical, mathematical and linguistic. The context is to be prepared before the assessment, and its concept lattice must be generated. The obtained concepts are called performance parameters (PP). They are involved in the evaluation process indicating to what extent a student is proficient in the skills that are included in the intension of a given PP. The suggested approach gives a more refined assessment of students because it emphasizes not only the knowledge that a student has gained but also his/her level in different learning skills.

## 3.1 Experimental Results

In order to gain real experience in educational applications of FCA, we made a mathematical test for grammar school students. Inspired by the evaluation method proposed in [5], we created a new technique for mapping the knowledge structure of the class and its members individually. The input data are stored in two different matrices. One of them is the student assessment matrix (SAM) which contains the test results. It has $n$ rows and $m$ columns, where $n$ is the number of students, $m$ is the number of test items and the entry in cell $(i, j)$ is 1 if student $i$ provided an acceptable answer for problem $j$ (otherwise the value is 0). The other matrix is the question skill matrix (QSM) which has $m$ rows ($m$ is as before) and $k$ columns, where $k$ is the number of categories in which the test problems are ranged. In our case the categories were specific fields of the learning material: geometry and trigonometry (GEO), equations (EQ), inequations and system of equations (INEQ), functions and sequences (FUNC), combinatorics and probability theory (PROB) and reading comprehension (RC).

The last category is for problems where a deeper interpretation of the text is needed to formulate the solution method. The (*i, j*) element of the question skill matrix is 1, is a skill belonging to category *j* is needed to solve problem *i* (otherwise this entry is 0).

In our case 15 students wrote the test, which contained 12 problems, and the result is in the top matrix of Table 2. Each of the 12 problems belongs to at least one of the six categories, as is represented in the second matrix of Table 2.

**Table 2.** Matrices used in creating the evaluation context

| SAM | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ST1** | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| **ST2** | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ST3** | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **ST4** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| **ST5** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **ST6** | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| **ST7** | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| **ST8** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| **ST9** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **ST10** | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| **ST11** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **ST12** | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| **ST13** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| **ST14** | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **ST15** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| QSM | GEO | EQ | INEQ | FUNC | PROB | RC |
|---|---|---|---|---|---|---|
| **P1** | 1 | 0 | 0 | 0 | 0 | 0 |
| **P2** | 1 | 0 | 0 | 0 | 1 | 0 |
| **P3** | 0 | 0 | 1 | 1 | 0 | 0 |
| **P4** | 1 | 0 | 0 | 0 | 0 | 0 |
| **P5** | 0 | 1 | 0 | 0 | 0 | 0 |
| **P6** | 1 | 0 | 0 | 0 | 0 | 1 |
| **P7** | 0 | 0 | 1 | 0 | 0 | 1 |
| **P8** | 0 | 0 | 0 | 0 | 1 | 0 |
| **P9** | 0 | 0 | 1 | 1 | 0 | 0 |
| **P10** | 0 | 1 | 0 | 0 | 1 | 1 |
| **P11** | 0 | 0 | 0 | 0 | 1 | 0 |
| **P12** | 0 | 1 | 0 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **SFV** | 4 | 3 | 3 | 3 | 4 | 3 |

We calculate the sums of the columns of the question skill matrix, creating the skill frequency vector (SFV). Its component *i* shows the number of usages of skills belonging to category *i* (the last vector of Table 2).

The students are evaluated by means of the concept lattice of the evaluation context (EC). This special context is generated by the following rule: the student assessment matrix and the question skill matrix are multiplied. Row *k* of the product matrix shows how many skills student *k* has from the different categories. This row is compared with the skill frequency vector, and student *k* is evaluated by the difference of these vectors. If the difference in component *j* is at most 1, student *k* has performed category *j* and the cell (*k, j*) is filled with an x in the evaluation context (otherwise the cell remains empty). At this stage the teacher has a possibility to refine the evaluation system; for example, full performance can be demanded in fields that are more relevant in the test.

This context can be clarified, which means that students with the same attribute lists are contracted into one object. With this contraction the evaluation context contains 9 objects, and its concept lattice consists of 9 concepts as well (Fig. 2).

| EC | GEO | EQ | INEQ | FUNC | PROB | RC |
|---|---|---|---|---|---|---|
| ST1 | | x | x | x | x | |
| ST2 | | | | | | |
| ST3 | | x | x | x | x | x |
| ST4 | | x | | | | |
| ST5 | | x | | x | | |
| ST6 | | x | x | x | x | x |
| ST7 | | x | | x | | |
| ST8 | | x | x | x | | |
| ST9 | x | x | x | x | x | x |
| ST10 | | x | x | x | x | x |
| ST11 | | | | | | |
| ST12 | | x | | | x | |
| ST13 | | | x | x | | |
| ST14 | | | x | x | | |
| ST15 | x | x | x | x | x | x |

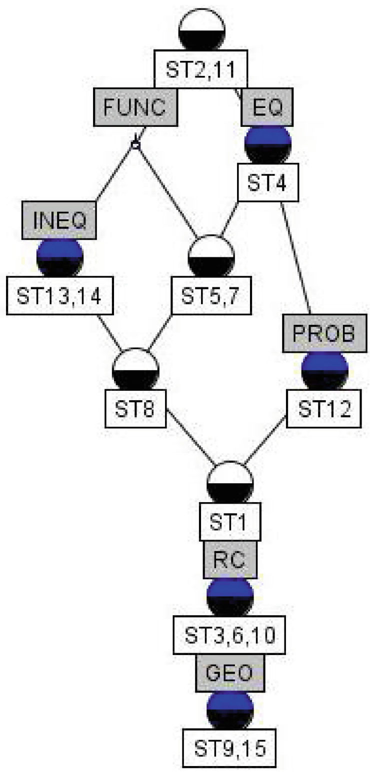


**Fig. 2.** The evaluation context and its concept lattice

The concept lattice can be used for a more complex assessment than the simple grading-by-points system. The lattice visualizes the knowledge hierarchy of the class: the better the student is, the lower level he/she is at. Students with the best results are at the root and the weakest students are at the top of the lattice. Using this hierarchy, the teacher can offer marks: he divides the lattice into horizontal zones and gives the same mark to the students who are at the same level. For example, a failing mark of 1 for ST2 and ST11, a passing mark of 2 for ST4, 3 for ST5, ST7, ST13 and ST14, 4 for ST8 and ST12, and the top mark of 5 for the others. Observe that ST4 solved more problems than ST13 and still got a worse mark, because instead of the number of the solved problems this evaluation system focuses on the number of the possessed skills and competencies.

The extent of a given concept contains a group of students, and the intent shows their common skills. From the viewpoint of the teacher the complement of this intent is much more important because it indicates the shortcomings of the students. If the class works on a project in different teams, the teacher can easily decide who should belong to each team, selecting pupils with knowledge that complements the others.

## 4 Conclusions

In this paper some applications of Formal Concept Analysis were discussed in the evaluation process. We created a special context starting from the classified list of test questions and test scores. The generated concept lattice proved to be a very useful tool in the visualization of the knowledge hierarchy and it provides a more complex evaluation method than a simple grading-by-points system.

## References

1. Singh, P.K., Kumar, C.A., Gani, A.: A comprehensive survey on formal concept analysis, its research trends and applications. Int. J. Appl. Math. Comp. Sci. **26**(2), 495–516 (2016)
2. Ganter, B., Wille, R.: Formal Concept Analysis, Mathematical Foundations. Springer, Heidelberg (1999)
3. Wolff, K.E.: A first course in Formal Concept Analysis. In: Faulbaum, F. (ed.) SoftStat 1993 Advances in Statistical Software, vol. 4, pp. 429–438 (1993)
4. Takács, V.: A Galois-gráfok pedagógiai alkalmazása. Molnár Nyomda és Kiadó Kft, Pécs, Hungary (2000)
5. Hans, S., Chakraverty, S.: A novel evaluation scheme using formal concept analysis. Int. J. Appl. Eng. Res. **11**(1), 479–483 (2016)

# Improving the Quality of Engineering Education by Developing the System of Increasing Students' Motivation

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**Abstract.** Currently, intellectualization processes cover all areas of activity, which is accompanied by an increase in the requirements for the competence of engineers. At the same time, interest of young people in obtaining an engineering education has decreased in many countries. The authors have studied the causes of this phenomenon. The article is devoted to analysis of relation between the quality of engineering education and the level of students motivation. Ways to increase motivation through the application of innovative technologies and creation the learning outcomes monitoring system are considered.

**Keywords:** Education quality control system · Motivation to study Engineering education

## 1 Introduction

Currently, the explosive growth of data amount is accompanied by the processes of intellectualization in all activity spheres. At the same time requirements to competence of engineers increase. Educational system should ensure the quality of training engineers, who are needed by business and society. At the same time, interest of young people in obtaining an engineering education has decreased in many countries.

The system of engineering education has been improved during the last years through the use of new capabilities that are provided by e-learning software tools. At the same time, authors of numerous studies note reduction of motivation to study engineering. This is due to the fact that increasing complexity of engineering and technology requires significant efforts from students when knowledge assimilation. Moreover, to be competitive, a student needs to possess certain skills in the chosen field of activity, and needs to develop the ability to make independent decisions during projects execution. The main goal of the research is the search of effective ways to increase students' motivation. To do this, firstly, the reasons for the decline in the young people's interest to obtain engineering education have to be identified. Secondly, learning process monitoring tool based on the "student-teacher" feedback should be created. This monitoring tool will allow us to adjust training courses that are not effectively assimilated by students.


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## 2 Motivational Factors and Their Impact on the Quality of Education

The educational system is quite inert in comparison with other types of large systems (social-economic, organizational-technical, etc.). This is due to the fact that pedagogical techniques and methods use technologies and developments from other spheres, although educational goal is personnel training for work in various fields. This contradiction is most distinctly reflected in engineering education, because the engineer generates new ideas that subsequently implements in the form of new products and technologies. That is, the educational system should develop the student's ability to develop technical skills and the skills of implementing technologies in different industries. Thus – the goal of engineering education - to prepare an engineer "for the future".

### 2.1 Motivation as an Incentive in Education

This goal can be realized only if the student has the ability to creativity. In addition, the motivation system plays an important role. In order to influence certain qualities of a student's personality, and also to formulate pedagogical goals, it is necessary to understand the priorities system, as well as the most effective methods (from the point of view of achieving results) of impact for each student and for the group as a whole. The educational system requires flexible an universal mechanism with the following functions: tracking changes in the external environment; an adequate response to these changes (adaptation of individual educational elements of the system to these changes); an introduction of these changes in the educational process.

Motivation is an internal energy that includes the person activity in life and at work. Motivation performs several functions: motivates behavior, directs and organizes it, gives it personal meaning and significance. In fact, the motivational sphere always consists of a number of motives: value orientation ideals, needs, motives, goals, interests, etc. If we talk about the students' motivation, then it represents the processes, methods and means of motivating them to cognitive activity, actively mastering the educational content.

It is based on motives, by which we mean specific expectations, incentives that force the person to act and do things. As motives can act in a bundle of emotions and aspirations, interests and needs, ideals and attitudes. Therefore, motives are complex dynamic systems in which choices and decisions are made, choice analysis and evaluation are carried out. For students motivation is the most effective way to improve the learning process.

Motives represent one of the mobile systems that can be influenced. Even if the choice of the future profession was made by the student is not entirely self-sufficient and not sufficiently conscious, then, by purposefully forming a stable system of activity motives it is possible to help the future specialist in professional adaptation and professional development. Careful study of the motives for choosing the future profession will make it possible to correct the motives of the teaching and influence the professional development of students. The effectiveness of the learning process is directly related to the high motivation and high stimulus for mastering the future profession.

Cognitive and social motives can be distinguished. If the focus on the content of the subject is predominant, then we can talk about the availability of cognitive motives. If the focus on another person is expressed, then it is talked about social motives. Both cognitive and social motives can have different levels: broad cognitive motives (orientation to mastering new knowledge, facts, regularities), educational and cognitive motives (orientation to mastering the ways of obtaining knowledge, methods of self-acquisition of knowledge), motives for self-education (orientation to purchase additional knowledge and then to build a special program of self-improvement).

Motives, even the most positive and diverse, create only a potential opportunity for a student development, because the motives realization depends on the goal-setting processes, those the ability to set goals and achieve them in learning. It is necessary to consider that motivation can be internal and external. The distinction of the concepts "internal motivation" and "external motivation" requires the establishment of some unambiguous criteria. In order to increase the motivation of students to engineering education it is necessary to formalize the criteria of motivation, to emphasize those ones that can be affected and to determine ways of possible actions.

Internal motives include their own desire to learn and their own development in the learning process. External motives come from parents, teachers, a group in which a student is studying, environment or society. The decisive importance should be given not to the external influence, but to the internal motive forces. In higher educational institutions it is possible to increase the students motivation in different ways, but the main methods of impact can be divided into three areas: first, the student needs to explain how the knowledge obtained at the university will be useful to him in the future. The teacher must be able to prove to the students that his subject will really be useful in his future work. Secondly, the student needs not only to interest the subject, but also to open for him the possibilities of practical use of knowledge. Thirdly, it is very important for the student that the teacher is his mentor so that he can be contacted for help during the educational process and discusses the issues that concern him.

### 2.2 Management of the Learning Process as a Way to Stimulate Motivation

The use of blended learning could become one of key solutions increasing motivation of problems existing in engineering education, because it allows: (1) more efficient use of time in classrooms, focusing on the problems faced by students, (2) identification of students experiencing difficulties, (3) picking up materials and assignments that are optimal to a particular group and a particular student, taking into account individual characteristics and a level of basic knowledge, (4) use of objective criteria when assessing students' knowledge, (5) improvement of motivation and education quality by implementation of progressive educational technologies.

Feedback is the most effective tool of the complex systems' reactive management. The educational system has considerable inertia due to the duration of specialist training process. That is why, the effective feedback is also a tool to overcome this inertia. The relationships between the teacher and students in such a system depend on the form of training. Most researchers note that blended learning is a modern, universal method of education focused on individual needs of students. The fundamental difference between blended learning [1, 2] and traditional system is a combination of organizational forms of training in real and virtual campus of the University as well as combination of traditional teaching methods with e-learning technologies. This combination can occur both at the training course and at the educational programs in general [3, 4]. Currently, expansion of opportunities of this interaction is accompanied with the expansion of the range of methods of educational process organization (e-learning, co-learning, blended learning, flipped classroom, etc.) as well as learning technologies (modeling [5], simulation experiments [6], gamification [7, 8], virtual and augmented reality [9–13], etc.).

In the system that we propose, education quality control is based on three-loop diagram (management of the quality of student's learning, management of the quality of the group's learning and management of the learning quality of the specific field of training). To assess effectiveness the system of indicators reflecting the quality of questions asked, the time for teaching, quality of responses, speed and regularity of work can be the criteria for evaluation of effectiveness of student's performance was developed. Correction of the process can be performed at each stage of learning within each control loop.

The process of specialists training F is determined by some goal Z. The state of the controlled object in this process is described by certain characteristics $X_i$. The process organization needs resources: external, received from the environment RC, and internal, belonging to the system R. At the output of the process, we have a product P, characterizing the competence, knowledge of the specialist. The output product quality (P) is adjusted during the process by means of certain control influences ($CI_i$), which are formed by the respective controlling bodies ($CB_i$) after analyzing the state of the controlled object in the learning process (F) (feedback). The process quality is controlled by varying resources supplied to the input (R).

In the scheme (Fig. 1), the controlled object is a student, an academic group, a student's course in a certain area of training, and also the educational process as a whole. The controlling subject is represented by the education quality control system. In addition, the control of the learning process is represented by three contours: the control of the student's state, the student group's state, and the control of a certain learning direction course's state. Since the state of the group and certain learning direction course

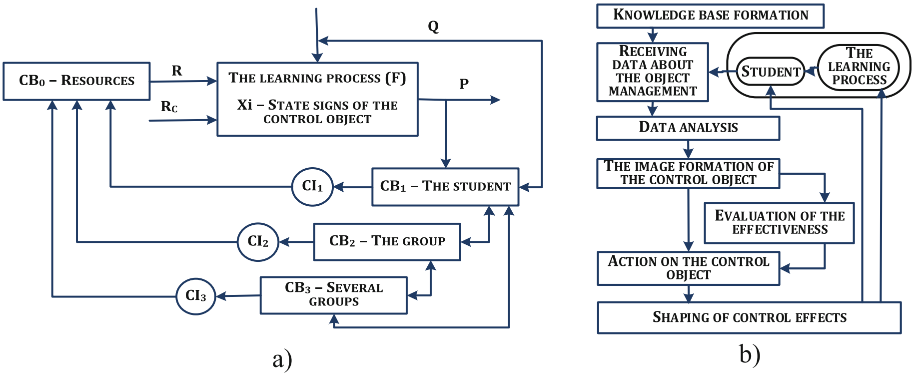


**Fig. 1.** The scheme (a) and algorithm (b) process of education quality control system

characterizes the quality of the learning process, the control actions will be directed at improving the educational process.

According to the proposed in Fig. 1a scheme, the generalized algorithm of the education quality control is a closed cycle (Fig. 1b). In the indicated algorithm, three basic control contours can also be distinguished: individually for the student; on the academic group (on the implementation of the impact on motivation); at the course of students in a certain area of learning in general (on the process).

In the first control contour, the main goal is to bring the student to knowledge in a certain way; in the second contour – the identification of problems and motivations of a particular students group; in the third contour – the formation of techniques and the implementation of resource management. In accordance with the standards of the ISO series, the first and second contour are aimed at ensuring the product quality, and the third - the process quality. The first and second contour are more dynamic and realize operational control by the specificity of the decisions being taken. The third contour characterizes strategic management, therefore it is more difficult to adjust.

Management in the framework of the first contour is aimed at identifying problematic places in mastering the material and motivating students. Correction of the learning process is carried out using those methods and tools that are more effective in stimulating learning activities in each particular case. In fact, this mechanism is one of the options for implementing situational management.

Modular open multi-user architecture of developed blended learning control system is the basis of reliability and stability of its work, as it allows quickly identifying and eliminating causes of failures, excluding their influence on other modules, and also increasing the speed and quality of technical support. This approach allows implementing all necessary functionalities and supplementing them when it is necessary.

## 3 Implementation of the Proposed Approach

### 3.1 Investigation of the Features of Different Categories Students' Motivation

The study of students' motivation features was carried out on the basis of analysis of the results of testing students' control groups. Group characteristics were the level of education (bachelor's, master's), course, group, learning direction, student's sex. The testing was conducted using different methods [14, 15]. Ilyina's methodology has three scales: acquiring knowledge, mastering the profession, obtaining a diploma. The adequacy of the professional choice and its satisfaction is characterized by the predominance of motives in the first two scales that do not characterize the motivation for learning, but reveal the criteria for professional motivation. The second methodology [14], on the basis of ranking technique reveals the dominant motives and provides additional information in their qualitative analysis.

Analysis of researches in the field of studying motivation for learning has shown that today the low quality of education is one of the most relevant problems, because many students are focused on formal signs (rating, marks, diploma), not on the content of education (knowledge that is necessary for professional activity). Many students do not want to study at university, but their parents force them and, as a result, there are completely un-motivated students today.

Another feature is the fact that current students are brought up to a greater degree by a TV and a computer. According to the students, they choose social networks, because they find there freedom from the adults' control, including actions based on antisocial desires. Young people who spend most of their time on the Internet, constantly overloading their brain with information, have atrophied motivation to learn, they become uninterested and can't keep attention [16].

We have studied motivation of the engineering students of automotive industry. In the course of the research, we concluded that the creation of a positive motivational sphere should include two mechanisms for the formation of motives through activity: "from the bottom up" and "from the top down", in addition, the structure of the motives should be taken into account. At the same time, one should also not forget that the motivation problems are also the problems of internal cognitive processes, motivations, choices [17]. An analysis of the motives structure for professional learning allowed us to put them in the following hierarchical order (Table 1).

**Table 1.** The structure of motives for the engineers professional learning

| Internal | External |
|---|---|
| 1. Awareness of the fact that knowledge is needed in the future | 1. Possibility to get a prestigious specialty |
| 2. Striving for success in the future | 2. The desire for self-fulfillment of abilities |
| 3. Self-reliance | 3. Competition |

The leading place is occupied by professional and social motives, connected with perfection and self-determination, and in essence they are semantic-generative [18, 19]. Using the modified method of diagnosing educational motivation, we identified the main groups of motives characterizing the professional learning process [14], and determined their average level.

Analysis of the research results (Table 2) shows that in this group of subjects, the predominant motives are professional (4.25) and communicative (4.2). The motives for creative self-realization (4.15) are on the second place. Educational and cognitive motives (4.1) are related to the content of learning activities and the process of its implementation, with the students' desire to obtain new knowledge, skills and abilities in learning. The following are social motives (3.9) and motives of prestige (3.8). These motivations encourage students to take a certain position in relation to others, gain approval from outside, to gain prestige, to achieve high professionalism and social status. In the last place, the respondents had the motive of avoidance. This means that students do not fear problems arising in their learning, they act so that they can be overcame.

**Table 2.** Students' motivation research results

| Scales | Average score |
|---|---|
| Communicative motives | 4.2 |
| Motives of avoidance | 2.6 |
| Motives of prestige | 3.8 |
| Professional motives | 4.25 |
| Motives for creative self-realization | 4.15 |
| Educational and cognitive motives | 4 |
| Social motives | 3.9 |

### 3.2 Application of the Modified Bloom Taxonomy in Blended Learning

The Bloom taxonomy offers a classification of the tasks assigned to the students by the teachers, and, accordingly, the learning objectives. It divides educational objectives into three spheres: cognitive, affective and psychomotor. These spheres can be roughly described with the words "I know", "I feel" and "I create", respectively. Within each individual sphere, for the transition to a higher level experience of previous levels, which is different in this sphere, is necessary. In his fundamental work [20], attempted to construct a hierarchy of educational goals encompassing the cognitive domain that would describe the levels of human thought and the resulting learning tasks step by step. Skills and abilities in the cognitive field relate to knowledge, understanding and critical thinking. From Bloom's point of view, learning goals directly depend on the hierarchy of thinking processes, such as remembering, understanding, applying, analyzing, evaluating and creating. Skills in the affective area reflect how a person reacts emotionally, how much he is able to feel someone else's joy or pain. Affective goals are related to human relationships, emotions, feelings. Skills in the psychomotor area describe the ability to manipulate implements or tools. Psychomotor goals are usually associated with a change or development of practical skills.

Accordingly each level a set of tasks can be given using certain verbs. Moreover, each level of the cognitive pyramid, according to Bloom, is based on the previous one. At the heart of everything is remembering, and the highest point of both cognitive abilities and learning goals is the ability to independently assess. It would seem that the idea is clear: without remembering and knowledge it is impossible to understand, without understanding it is impossible to use, without mastering the initial levels, analysis and evaluating are impossible, and without all this creative evaluation of phenomena's and events is inconceivable. However, according to scientists, this is precisely the lack of taxonomy Bloom: in his hierarchy the concepts of different orders are mixed, namely the concrete learning outcomes (remembering, understanding, applying) and the thought operations necessary to achieve these results (analyzing, evaluating, creating).

Given the shortcomings of the Bloom taxonomy many scientists use the proposed hierarchy to create modified methods for systematizing tasks aimed at the intellectual development of students. Thus, recently in Alan Carrington's blog the model called "Pedagogical Wheel" has appeared. The principles behind this pedagogical tool are universal when applied to any technology device. "Pedagogical Wheel" combines the goal of Bloom's taxonomy, SAMR model of educational technology and different variants of the use of iPad applications, helpful for the relevant group. For example, in the opinion of Alan for remembering and understanding levels the applications Facebook, GoogleSearch, Twitter, BlogDocs, MentalCase, DocsToGo, QuizCast, FeedlerRSS, etc. are suited perfectly. To develop and improve the applying level – Evernote, AudioBoo, ExplainEverything, Keynote. To develop analytical skills – Mind Mush, Syrvey Pro, Poplet, Inspiration Maps, Pages, DropVox, Comic Life. The ability to evalueting is best manifested in WikiNodes, Web to PDF, Share Board, Prompter Pro. Ability to evaluate and create something is needed more than all in the applications Creative Book Builder, Interview Assistant, Aurasma, Fotobabble, iMovie, WordPress, Skype, Tapose, Google+, Student Pad.

Thus, having formalized motives of students in educational activities, as well as formalized methods of abandoning tasks that can influence these motives and tools to stimulate motives, we receive a tool for managing the learning process.

## 4 Actual or Anticipated Outcomes

### 4.1 Preliminary Stages. Formation of Information Bases

At the first stage, questionnaires were developed and a survey among employers and among students was conducted. We have systematized the tasks to be solved by engineers at their workplaces. First, specialists of partner companies were interviewed to reveal the competences of university graduates most meaningful for their performance and career, and also which software and technical solutions are applied in practice.

The survey findings were processed and systematized in respective categories (Table 3). The survey among employers has revealed problems for different areas of engineering that are experiencing young professionals. The survey among students has helped to define the most challenging problems they faced during the training period.

Motivational characteristics and learning process quality assessment criteria were formalized. When developing the classification system a modified Bloom's taxonomy was used. During the research experimental groups of students of different training areas (design, technological, service, and also in the field of information systems and technologies) were formed. In conjunction with this the formation processes of general professional, special professional, instrumental and social competencies were studied. Studying of questionnaires has revealed the most important motivation criteria and their correlation with personal characteristics and abilities to intelligent actions and decision-making. At the second stage, the goals were formalized and informational bases which summarize the results of preliminary research were formed.

**Table 3.** The results of the employers questionnaire in terms of competences

| The competences | | Functions of the business | | |
|---|---|---|---|---|
| Groups | Names | 1[a] | 2[b] | 3[c] |
| 1 | Fundamental knowledge | 90 | 30 | 40 |
| | Engineering knowledge | 90 | 30 | 50 |
| | Application IT for the decision of professional problems | 70 | 50 | 65 |
| | Understanding of problems of life cycle of a product | 90 | 40 | 40 |
| 2 | Creative and critical thinking | 80 | 40 | 60 |
| | The initiative | 90 | 85 | 80 |
| | Ability to constant perfection | 90 | 90 | 90 |
| | Ability to end in itself and planning of the career | 95 | 94 | 90 |
| 3 | Engineering thinking | 98 | 50 | 60 |
| | Ability to the decision of professional problems | 95 | 95 | 92 |
| | System thinking | 95 | 40 | 70 |
| | Ability to search and the information analysis | 95 | 85 | 80 |
| | Awareness in engineering tendencies | 98 | 60 | 70 |
| 4 | Ability to work in collective | 80 | 90 | 90 |
| | Knowledge of methods of business communications | 90 | 75 | 85 |
| | Communications in foreign languages | 90 | 70 | 70 |
| | Ability to successful work in the organization | 95 | 95 | 95 |

Groups of competences: 1 - technical; 2 - personal; 3 - professional; 4 - Interpersonal and communicative; [a]Designing and manufacture of vehicle's and intellectual systems of the vehicle; [b]Management in transport and logistical systems; [c]The organization of transport processes and safety of transport systems.

### 4.2 Testing the Hypotheses. Carrying Out Experiments

The third stage consisted in testing the performance of the system proposed. For this, we formed experimental study groups to be taught with the aid of the developed methods and technologies. For instance, with students majoring in car design (automobile- and engine construction) emphasis was laid on designing of intelligent car systems. These students studied 3D modeling, engineering analysis and imitation modeling using the Siemens PLM software complexes.

The students majoring in automobile electronic systems, were trained in developing of intelligent electronic management systems with a focus on engineering analysis and construction of functional schemes using the Siemens NX, e-Series software complexes.

The students that intending to work in technological centers of auto-manufacturing companies studied the SiemensPLM programs: Plant Simulation and Tecnomatix (with Jack and Human Performance modules). These programs are used by manufacturers to perfect the technological processes on virtual mannequins (Fig. 2b).

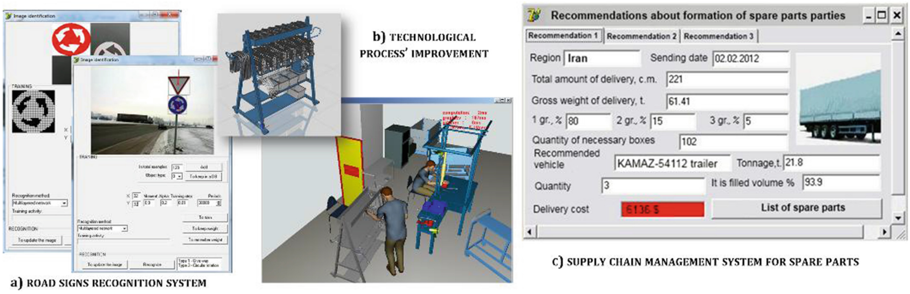


**Fig. 2.** Examples of students' graduation projects

Students, majoring in logistics and operation of automotive transport, studied the theory of management of transport vehicles and transportation flows, methods of logistics optimization, telematic systems, and GIS using the MiniTab, PTVVision (VISSIM, VISUM), ArcGIS, and MapInfo software.

By participating in real projects, the students got a better idea of requirements imposed on modern vehicles and developed them by employing new design technologies. Their graduation papers were later extended in their master's degree studies.

The issues of transportation planning and simulation are dealt with in different companies. There are companies creating the infrastructure, building and reconstructing the street-road networks, determining the location of sites for public transport stops, petrol filling and service centers. Others are involved in planning of traffic along the street-road networks and of traffic control with the purpose of enhancing its safety and effectiveness.

Engineers in these companies must know how to obtain adequate information and operate with big dates, analyze them and make strategic and operative decisions. Training for these positions envisages instruction in the systems theory, intelligent control systems, statistical data analysis, the theory of experiment planning, and methods of optimization. In this case, both the course and graduation projects of the students are to include such points as constructing of models of a street-road network site, revealing the causes of hindered traffic in a model, and searching for variants of optimizing the traffic parameters at the site in question (Fig. 2a).

Markets globalization has made important the issue of judicious organization of logistics processes. The engineers involved in cargo delivery must know the means and methods of cargo shipment planning and managing of motor vehicle fleets, methods of building logistical chains accounting for interaction of different kinds of transport (Fig. 2c). They must also be trained in how to select the optimal routes with account for different factors and risks.

These aspects are studied by doing such courses as statistical data analysis, methods of planning and forecasting, theory of constraint, systems analysis methods, theory of experiment planning, management in logistical systems, and the theory of transport flows. The course and graduation projects include the issues of constructing of logistical systems, selecting of optimal logistical chains, rational warehousing logistics, building of optimal routes, and motor vehicle fleet management.

As can be seen in the presented examples of students' projects, the students solve real problems which help them to understand the problems of the industry and professional tasks already during their study time. This approach facilitates professional adaptation. In our opinion, developing of a high-quality study content in the simulation environment later to be used at real workplaces will improve both the students motivations, quality of engineer training and the learning process management in realization of the "life-long learning" concept [21].

## 5 Conclusions

In our opinion, the developed system of the educational process quality assessment together with formalization of the motivation criteria allows evaluating the effectiveness of new learning technologies and methods of educational process organization. In addition, it will help to realize the principle of educational trajectory individualization for students with different backgrounds and personal characteristics.

Advantages over traditional techniques:

1. For business: reducing the adaptation time of the graduate at the enterprise; increasing of the graduates' training level; the graduates have the necessary business competencies.
2. For the student: increasing interest in the studied subjects; the ability to solve problems of the real production; increasing competitiveness in the labor market.
3. For the educational system: increasing of engineering education prestige; the possibility to cooperate with business more closely; improving the quality of education.

In addition, interaction with business will allow teachers to learn new technologies and apply them in educational process.

## References

1. 6 Models of Blended Learning. http://www.dreambox.com/blog/6-models-blended-learning
2. Norberg, A., Dzuiban, C., Moskal, P.D.: A time-based blended learning model. On the Horizon **19**, 207–216 (2011)
3. Karabulut-Ilgu, A., Jahren, C.: Evaluation of hybrid learning in a construction engineering context: a mixed-method approach. Adv. Eng. Educ. **5**, 1–26 (2016)
4. Bonk, C.J., Dennen, V.: Frameworks for research, design, benchmarks, training, and pedagogy in web-based distance education. In: M.G. Moore (ed.) Handbook of Distance Education, pp. 331–348. Routledge, New York (2013)
5. Zawojewski, J.S., Diefes-Dux, H., Bowman, K.: Models and Modeling in Engineering Education, 35 p. Sense Publishers, Rotterdam (2008)
6. Balamuralithara, B., Woods, P.C.: Virtual Laboratories in Engineering Education: The Simulation Lab and Remote Lab. http://onlinelibrary.wiley.com/doi/10.1002/cae.20186/abstract
7. Çakıroglu, U., Basıbüyük, B., Güler, M., Atabay, M., Memis, B.Y.: Gamifying an ICT course: influences on engagement and academic performance. Comput. Hum. Behav. **69**, 98–107 (2017)

8. Yáñez-Gómez, R., Cascado-Caballero, D., Sevillano, J.-L.: Academic methods for usability evaluation of serious games: a systematic review. Multimed. Tools Appl. **76**, 5755–5784 (2017)
9. Bhoir, S., Esmaeili, B.: State-of-the-Art review of virtual reality environment applications in construction safety. In: AEI 2015, pp. 457–468 (2015)
10. Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M.D., Mora, C.E.: Augmented reality to promote collaborative and autonomous learning in higher education. Comput. Hum. Behav. **51**, 752–761 (2015)
11. Ribón, J.C.R., Villalba, L.J.G., Kim, T.: Virtual learning communities: unsolved troubles. Multimed. Tools Appl. **74**, 8505–8519 (2015)
12. Webel, S., Bockholt, U., Engelke, T., Gavish, N., Olbrich, M., Preusche, C.: An augmented reality training platform for assembly and maintenance skills. Robot. Auton. Syst. **61**, 398–403 (2013)
13. Wu, H.K., Lee, S.W., Chang, H.Y., Liang, J.C.: Current status, opportunities and challenges of augmented reality in education. Comput. Educ. **62**, 41–49 (2013)
14. Badmaeva, N.C.: Vliyaniye motivatsionnogo razvitiya na razvitiye umstvennykh sposobnostey, 280 p. Izd-vo VSGTU, Ulan-Ude (2004)
15. Metodika izucheniya motivatsii obucheniya v vuze T.I. Il'inoy. http://testoteka.narod.ru/ms/1/05.html
16. Khagurov, T.A., Ostapenko, A.A.: Reforma obrazovaniya glazami uchiteley i prepodavateley: opyt sotsiologicheskogo issledovaniya. Ins-t RAN; Ros. akad. sots. Nauk, Krasnodar. regin, 107 p. Otd-ye.- M.-Krasnodar, Parabellum (2013)
17. Milligan, C., Littlejohn, A.: Why Study on a MOOC? The motives of students and professionals. Int. Rev. Res. Open Distrib. Learn. **18**, 92–102 (2017)
18. Graven, O.H., Bjørk, J.: The use of an Arduino pocket lab to increase motivation in Electrical Engineering students for Programming. In: 2016 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), pp. 239–243 (2016)
19. Wang, Y.-H.: The effectiveness of integrating teaching strategies into IRS activities to facilitate learning. J. Comput. Assist. Learn. **33**, 35–50 (2017)
20. Bloom, B.S.: Taxonomy of Educational Objectives Book 1: Cognitive Domain Paperback. David McKay Company Inc./Longmans, New York (1956). 207 p.
21. Bengoetxea, E., Kallioinen, O., Schmidt-Jortzig, I., Thorn, R.: Quality Assurance in Lifelong Learning, 32 p. European Association for Quality Assurance in Higher Education, Brussels (2011)

# Data Processing, Systematic Errors, and Validity of Conclusions in Education Research

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**Abstract.** The aim of the present study is the investigation of the validity of various results in education research, due to the way these have been derived from the data taken. The use of simple statistical tools for data analysis is seen as the mail culprit, leading to results that are not supported by the quality of the data taken. The repeated use of purely statistical tools, albeit simple in execution and convenient as they really are, ignores the presence of systematic (non-statistical) measurement errors. It is precisely this failure during data analysis that very often leads to erroneous results. The non-repeatability of various experiments is thus explained, while some suggestions are offered to improve the situation.

Systematic error estimation and Random error computation should be used to determine the total experimental error (or uncertainty) for each and every data-point of primary experimental data-plot. Subsequently, full error-propagation techniques need to be used to find the final error for each point, so as these can be reliably utilised to make valid comparisons and finally derive valid experimental results.

Naive utilisation of simplistic statistical functions is to be curtailed, while more precise information needs to be factored in and be properly evaluated, so as conclusions would be unequivocally valid.

**Keywords:** Data processing · Education research · Statistical errors
Error propagation · Research methodology

## 1 Introduction – The Non-repeatability of Various Experimental Conclusions

During the past few years it has become apparent that a great percentage of experimental measurements (in various fields of human knowledge) many of which were published, give results impossible to be verified by other experiments that, although they measure the same quantities, they do so using different experimental setups. There is, therefore, a direct challenge as to the overall validity of what they insist are results and conclusions. Total confusion is the outcome. Whom should one believe? In an article that is consistently one of the 5 most cited papers ever [1], it is mentioned that "most current published research findings are false", for most experimental designs and for most fields of knowledge. Also: "for many current scientific fields, claimed research findings may often be simply accurate measures of the prevailing bias". Also that: "there is increasing concern


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that in modern research, false findings may be the majority or even the vast majority of published research claims", and that "it can be proven that most claimed research findings are false".

In educational research, we measure knowledge and educational effectiveness, the measurable quantities of which are indirect and more obscure (in comparison to medicine, for example), and the effects dealt with are more complex and often far more obscure and enigmatic. An added factor that gives urgency to the matter is that in education one has to often wait for decades to see the overall effect of bad teaching practices (- compare this with medicine, for example).

## 2 The Real Cause of This Predicament in Education Research

It should, therefore, be considered as a certainty that there is a potential problem in education research - irrespective of field. Two corroborating factors support this view. To start with, very few researchers specifically aim to verify previous research – be that their own or of others. Furthermore, macroscopic observation of published experimental articles would verify directly that very few articles admit failure in any type of educational trial, something most improbable, and which can only be explained by a proliferation of "false positive" biases. Both these observations were first noticed in fields like medicine, where the "questionable data-handling" discussion arose. Although the present study will use exclusively examples from the fields of Science Education and Engineering Education, there are reasons to believe that the problem is not confined to those but that, indeed, it is shared with other fiends of Educational research.

The causes of the non-repeatability of experimental results are complex by nature, and each time diverse in detail. However, the main cause is the incorrect handling of systematic errors for each measurement, whether these are biases (which could potentially be assessed) or belong to the category of "remaining systematic errors" (in which case they should be estimated and taken into account when determining the overall experimental error). Summing-up, the first cause is the imprecise application of measurement methodology and overall research methodology, which are so meticulously followed in every field of Natural Science.

The second cause of the non-repeatability of experimental results is the simplistic use of simple statistical methods and statistical functions during data processing. The basic advantage of such practices is that they are simple in execution. Indeed, they even tend to become formalised and to be used with a scant (if any) understanding of their particular limitations, mainly due to lack of rigorous training amongst researchers of numerous experimental groups. Enhancing and intensifying the aforementioned cause (i.e. the incorrect handling of systematic errors), is the derivations of results. These are often simplistic and not supported by the real measurements. Summing-up, the second cause is the negligent, slack, and imprecise use of real Statistical Inference methods, Probability theory, and Decision theory, i.e. overall lax use of Mathematics.

## 3 Experimental Errors and How They Differ from "Mistakes"

The following notes concern measurements of any type or form, and they, therefore affect research in all subjects and fields, be they Arts or Science, or even their applications. They apply very time a measurement is taken, or an observation is made, of any quantity, no matter how the measurement is made. It affects measurements taken using a questionnaire as much as those using a voltmeter.

Each and every measurement of any quantity are affected by an **uncertainty** which we call to be an "error". The concept of an "error" is, therefore, fundamentally different from a mistake, and these concepts should not be mixed-up. Measurement errors, or observational errors, can be categorised as follows: (a) Systematic errors and (b) Random (or Statistical) errors.

These two error categories can be computed and subsequently summed-up, so as to derive the final measurement error. As the aforementioned two error categories are intrinsically independent from each other, their summing up is achieved using vector algebra. Independent quantities imply vectors vertical to each other, just like adding up speed vectors in two directions, or when computing the complex resistance of an RLC circuit. The final experimental error thus computed, is different from each measurement in each and every diagram, or experimental histogram. As errors signify a quantification of the uncertainty of each measurement, this error differentiation is affecting directly: (a) comparisons between different measurements in the same diagram and (b) any comparison attempted between measurements depicted in different diagrams. If, for example, one compares responses from two student samples, the final experimental errors depend not only by the size of each sample, but also on the respective responses measured from each sample. More specifically, if the two measurements correspond to "student ideas" before and after an educational trial, and one tries to assess the effectiveness of the new teaching approach, the final measurement error should be computed for each experimental point of each of the diagrams one directly compares. It is even dependent on the actual number of students that have the particular misconception, as a percentage of the total number.

No objective value can be assigned to any type of experimental result without an objective estimation of the measurement errors of the measurements on which this is based. Because, the assessment as to if there is a distinct difference between the compared experimental points is directly dependent on the uncertainty (and hence the error) of the measurements, irrespective of the nature of the quantity measured.

## 4 Systematic Errors

Systematic errors are non-random errors, but they do limit the reliability of the measurement. Being non-random they remain unaffected by the size of the sample or the number of times a measurement has been repeatedly taken. Their source varies, and as no experiment can avoid all causes of such errors, no research of any type can achieve zero systematic errors. They are omnipresent to every measurement and (despite being common practice in some fields of human knowledge) its estimation should not be avoided, no matter how difficult this may be. If one does not attempt to estimate systematic errors incurred, this is tantamount to a tacit acceptance that such errors do not exist (- and this is a serious mistake being committed).

There are two subcategories of systematic errors: (A) Biases or (b) "Remaining Systematic errors" which contribute to the overall measurement error even after all subtractions and proportional reductions. It should be noted that if there is an experimentally valid method to actually measure the biases, then these can, and indeed should, be subtracted from the measurement made. If, however, there is no way to reliably measure or even to estimate the bias occurred, (as for example when we do not even know if it tends to increase or decrease the numerical value of the measurement) then, precisely because any attempt for bias correction is futile, it is essential during data analysis to ***increase*** the estimate of the "Remaining Systematic error".

There have been a number of attempts to classify the systematics taking into account their source, in an obvious effort to reduce them as much as possible or to estimate them in a more quantifiable manner (see for example [2]). It should be noted that such classifications are unrelated as to if these errors are classed as biases or not. Especially for educational research, notable, amongst sources, are the selection biases, the information errors, and the confounders.

It should be stressed that by avoiding dealing with systematics during data analysis is equivalent to ignoring unpleasant realities. It is figuratively "burying one's head in the sand" and by doing this we often destroy the actual evidence and end-up with totally erroneous results. During an experimental measurement it is inevitable to be affected by systematics, but although this is well understood, in order to measure or even estimate this, one needs to compare the method or the instrument used with another (presumably more accurate) "standard".

As an example, let us consider an attempt to measure a certain length of 8 m using a 1-m tape measure. If, due to manufacturing problems, this is not precisely 1 m long, but 99.8 cm instead, the length would be measured as 798.4 cm. The potentially consistently imprecise (as opposed to erratic) practice by the experimenter while using the tape measure would result in an additional systematic error on top of the previous one. Other example from Physics experiments is the attempt to measure the magnetic field using Hall-probes (instead of the more precise but cumbersome NMR probes) or acceleration measurements using simple Micro-electro-mechanical systems (MEMS) instead of high precision accelerometers. In both such occasions, the more precise instrument can be used afterwards to correct the previous data taken. Such systematics are biases, and should be subtracted so as the final measurements would be devoid of such known errors. This error subtraction is often complex, however, and in such occasions experimenters have to use specialised and computationally intensive "**Monte Carlo**" simulation techniques. Discussion of "Monte Carlo" techniques is beyond the scope of the present study, but it should be noted that they really represent the only way to achieve measurements as precise as modern High Energy Physics experiments or Astrophysics experiments.

Other most common (albeit specialised) example of bias-type systematic error in medicine is the so-called "placebo effect", contributing to some type of virtual cure. The corresponding example in Science and Engineering education is the (real) improvement in the knowledge achieved simply because of the novelty effect (new teachers, new media, new methods), which precisely as the placebo in medicine is always positive in its effect (i.e. increasing actual knowledge gained, through increased attention). Although meticulous researchers always use a “control group”, in practice this is not always done. Furthermore, how similar can the two sample-groups be, and could it perhaps be that there is also an increased “placebo effect” in the experimental group due to the greater amount of novelty – as the use of ICT or something new in general? All these would result in “false positive” bias. Although such effects are to be expected, how can an experimenter quantify such effects, in any given experiment?

Some systematic errors are truly impossible to be computed using a new and more precise measurement i.e. a more precise overall procedure. Coming back to the aforementioned tape-measure example, not only is the tape that needs to be more accurate, but the measurement procedure would also need improvement and increased precision requires more time. What if there is no better and more accurate tape measure? If such an improved standard is indeed available, how certain can we be about its own accuracy? In educational research, how representative is our sample of children in the particular school used, and how do the teachers in previous forms these children have had relate to the national mean? All these are typical “selection errors”. However, all these form only part of the overall picture. For example, how much confidence can we have to the precision of the measuring procedure used? (E.g. the questionnaires, these being only a part of the procedure). If the sample had involved many teachers and many schools, how alike are all teachers participating in the trial? How representative are these teachers in relation to the national average? Does their age play an effect? It is precisely this uncertainty about the actual (so to say) “tape-measure” used as well as the overall procedure that was followed that results in the numerical value of the “Remaining Systematic error” for every particular measurement. There are numerous sources to that effect. For a complex measurement (like a questionnaire measuring students’ knowledge and misconceptions) the remaining systematics are much greater, precisely because measurements are so complex. For example, how clearly explained is each question in the questionnaire, and how easy is for each student to comprehend what is asked from him? Are the questions equally comprehensible? (- This is, in case one attempts an internal comparison between the entities taught). Such examples are numerous.

In conclusion, in Arts subjects (including Humanities, Science Education and all similar research), the Systematic errors are in reality especially large and in most occasions constitute much the largest part of the total experimental error. This may be annoying to some, but it is nevertheless true.

It should be stressed that (contrary to popular misconception), ***when the sample is large, the relative importance of the “Systematic Error effect” is increased!*** This is precisely because, due to the increased sample, the contribution from the statistical (random) errors in decreased, whereas that of the systematics remains unchanged, or (as it is often the case) it is numerically increased for various reasons. While the researcher rests assured about the validity of his results, the real picture does not justify such wishful thinking.

## 5 Random or Statistical Errors

Random errors or Statistical errors are errors that affect all measurements in a random manner, and because of this, they cannot be deducted during data processing. Contrary to the aforementioned systematics, most researchers are very familiar with this category of error. If one repeats taking the same measurement, the result may differ somehow. Contrary to the systematics, random errors can be decreased by the simple expedient of increasing the number of times we take the measurement. Therefore, they can be dealt with using statistical theory, and from this comes their second name - Statistical. In essence, these are errors related to the precision of each singular measurement and exhibit all types of variation when all other parameters are kept as constant as possible – thereby resulting in numerical measurements distributed around a “mean value”. Measurements affected by Random errors often (albeit not always) exhibit a Gaussian distribution. In case those measurements really follow such an ideal distribution, it is possible to use relatively simple statistical methods to study the random errors.

Examples relating to the source of random errors include any normal differences in competence between students of the same class (or classes) forming an experimental sample. Such samples are considered homogeneous without this being necessarily the case, as every teacher knows very well. A random lapse of attention from a student while answering the question is another such example or a slight sickness during that day might have the same effect, or alternatively something that he may have watched on television a few days earlier. On the contrary, if all students in a class have watched an educational video in class a few days earlier (perhaps under the supervision of a different teacher) this would have turned (i.e. relegated) this error into a systemic bias affecting the measurements positively or negatively (depending on the content, quality, and validity of the video). In general, random errors are inevitable, as all educational research uses groups of individual students, and joins them into a single sample.

Concluding, it is rather obvious that simply quoting the total sample N of the students’ sample participating in a research is insufficient, if not outright misleading, in relation to the overall validity and overall value of any conclusion reached. This is true irrespective of the field and subject of the research, be that in Arts, Letters, Humanities, or Science.

## 6 Measurement Tools Available: Questionnaires and Interviews and How We Err Using Them

The **Validity** of a questionnaire (or any such “tool”) is a concept fundamentally different and only indirectly related with the concept of **Reliability**. Whereas validity examine the extent to which the “tool” measures precisely what it is trying to measure, reliability measures whether or not the “tool” measures something (anything, in fact) in a way that is consistent and repeatable [3]. Whereas any tool cannot be valid (at least not in any experimentally useful manner) without being reliable to start with, the opposite is not necessarily true. Indeed, the tool might be consistent and still be measuring something different to what was intended to measure. Therefore the two concepts are radically different from each other, the reliability being an essential precondition so as the tool could (potentially) be valid.

In conclusion, if a questionnaire has been used successfully in the past, is not even a slight indication that it is valid. The very concept that a tool (questionnaire or interview procedure) can be considered as “a priori” valid does not even exist – it is literally preposterous! On the contrary, the validity of any questionnaire used should be proven “a posteriori” that is after its use, and after the data-taking procedure is finished. The proof of validity should form a pivotal, crucial, and indispensable part of the data-analysis process. Therefore, the researcher should be fully prepared in case his questionnaire proves to be invalid in his case, and not even a preliminary testing procedure could ever possibly give total assurance.

Why? What is the underlying reason for this effect? From the viewpoint of an experienced experimental Physicist, the real difference between the concept to validity and reliability is the existence of Systematic Errors, which (as aforementioned) are a radically different category of error to the random (or statistical) ones, and hence they are obviously impervious to sample size N.

Irrespective if the sub-category to which they belong (be they biases or remaining systematics), the systematic errors are the underlying reason for the profound difference between validity and reliability. Indeed, if a tool has proven itself valid during a previous research (with whatever systematic errors this may have endured), this fact does not even stand as a first indication that it is still valid for a later research, with its very own new systematic errors (-these being completely different from the previous systematics both in nature and in size, as it is a different research setup).

## 7 The Nature of the Problem During Data Analysis

By their very nature, Systematic Errors are very hard to be evaluated. Furthermore, each and every mathematical operation (e.g. multiplication or division) that is performed on the raw data, results on a change of the size of the total experimental error computed using these raw data. The error is therefore “propagated” so as to form the error on the final experimental results. Although the total error changes with the operations performed, it is never actually reduced: on the contrary, it can always increase in size. The underlying reason for this predicament is the second law of thermodynamics (i.e. the constant increase in Entropy), as this Law is applied in Informatics (like Computer Science) by Claude Shannon. Although performing such an “error-propagation” computation for every final data point in the results presented is a well-established procedure, it is very rarely performed. Indeed, this procedure is only really practiced in various disciplines of hard Science.

At any rate, a well-known and trusted method for an estimate of the quality of the experimental data by the researcher is by careful and considered look at plots and graphs of the data taken, and the detailed comparison between them. This being a kind of black art, it also requires lengthy apprenticeship to be mastered – and the masters of such art are themselves Scientists.

## 8 Hypothesis Testing as a Means to Draw General Conclusions from Experiments and Tests

The simplistic use of statistical functions (of non-Bayesian statistics), such as the "Kuder-Richardson coefficient of reliability (KR-20) (for binary data), continues unabated. So is the persistent use of its modification by Hoyt and popularised as "Cronbach-alpha" (for non-binary data, e.g. those asking students not if they agree but the extent to which they agree with some statement). What is not wise is the use of such functions to evaluate questionnaires. Such functions are only capable of measuring the "internal consistency" of a particular use (i.e. a trial) of a questionnaire on a given sample. They are therefore measuring only an aspect of the reliability of that questionnaire [4]. More specifically, what is measured is how much the answers to questions of a questionnaire are related with each other (considered in pairs). Be that as it may, to a certain extent, the various questions of the same questionnaire measure truly related aspects of students' opinion (often done deliberately by the questionnaire designer as a method of self-consistency).

Furthermore, the "internal consistency" is not quite the same as the consistency. Despite having similar names, these concepts are quite different as: (a) the "internal consistency" measurement is valid only for the specific measurement, with the specific sample and measurement conditions. (b) It blindly measures the arithmetic between the answers in all the questions, in pairs. (c) The final value of the function depends on the overall number of the questions in the questionnaire, and the extent to which these questions are related with each other (conceptually and verbally). Therefore, in what sense could such a function ever reveal whether or not the questionnaire is measuring opinions, in a consistent and repeatable manner?

Very often, the use of such functions is associated with some kind of preparation and checking so as a "hypothesis testing" procedure be applied. Such practices are common in Medicine or Psychology as they do offer answers to questions like whether or not a certain substance can be considered as a medicine or not. Alternatively, they indicate whether or not a certain hitherto hidden parameter can be the common cause for some (or all) the observations in the experimental test. In education, what is under scrutiny is (instead of a medicament) a new form of teaching procedure. It is reminded that, even during the aforementioned correct use of such functions, these should always be applied after each use of the questionnaire and for each new sample of students (i.e. a posteriori). It should never be assumed that previous uses of the same questionnaire in different experimental trials offer any kind of assurance as to its validity [5]. For educational research, the use of any hypothesis testing seems to be all too simplistic, even conceptually. Here, answers can rarely be binary (e.g. is this a medicine or not), and hence the use of such functions and procedures can be seen as unnecessary, improper, or even deceiving. Because, the question posed is not simply whether or not the use of any new device or software helps student's knowledge or not. On the contrary, the real question always is how large was this understanding for each of the concepts taught, and how this can be maximised in practice. The study of students' ideas (and misconceptions) before and after the novel teaching procedure is the real (albeit often subliminal) experimental target of all types of education research. This target would naturally lead to the analysis or every question in the questionnaire on an individual basis and every misconception in an effort to find an order within this disjointed maze of human beliefs and thinking patterns.

It emerges, therefore, that no matter which numerical values are derived by the various statistical functions (there are quite a few), these are not very useful at all, because they are twice removed from measuring the validity of anything in particular. Firstly because the **internal consistency** measured is patently not the same with **reliability**. Secondly, because reliability is radically different from **validity**. For example, it is a well-known fact that the value of the aforementioned KR-20 and Cronbach-alpha increases (numerically) as the number of questions of the questionnaire increases [6]. Furthermore, the finer the differences between these questions become (as when one examines a narrow range of concepts in a finer detail), the larger the numerical values become. After all this, how can such functions ever be considered as candidates for measuring and supposedly proving the validity of any testing?

Various authors, including the one undersigning the present study, have expressed grave concerns in the past about the omissions of the error-bars in studies what claim some measure of objective validity in their conclusions. “Where are the error-bars in social-science journals” [7] under “deficits of hypothesis testing” [7, 8]. Therefore, serious doubts have been expressed concerning the simplistic use of various functions during data analysis, pretending that they are a kind of “simple statistical inference” while they are nothing of the sort. How can one justify the audacity of reaching conclusions (supposedly), from such ill-supported data-handling procedures?

Furthermore, on matters of Science and Engineering education, any attempt to oversimplify by asking a general (yet simplistic) binary question of the type “is the use of such and such a tool good or not”, should be viewed with much healthy scepticism. This is not a matter of searching for a medicinal cure. Asking the much more complex question: “how educationally useful is such a teaching procedure (or tool) for the teaching of which subjects and concepts, at what age, and using what didactical method” is the right thing to do, and the relevant question to ask.

## 9 Statistical Significance Evaluation Is Impervious to the Most Significant Source of Experimental Errors

It is only natural to use all types or statistical functions in the procedure controlling raw data. However, it cannot be stressed enough that the precision of numerical results computed by such functions is limited by the extent to which the data fall under some preconditions associated with such functions. The most common condition is for the error distribution of the data to be Gaussian.

Let us consider a simple yet totally general example, like the simple comparison between the percentages of “correct answers” between two student groups A and B. Let it be that the mean value of A is numerically less than that of B. The researcher asks the simple question: how certain are we, that A is less than B? Is it possible that, despite the mean of A being less than the mean of B, in reality the opposite may be true? Or, perhaps, could it be that there is no distinction between the two values, them being virtually identical in reality? In order to reach an arithmetic answer to this important research question, we should assume some "probability distribution" for the data measured. Even a simple discussion of all simple "probability distributions" and their applicability would require many pages. Now, if we add to the above already precarious position the unquestionable existence of sizeable systematic errors (which potentially alter the aforementioned distributions quite considerably), the real question becomes quite different. It is "what is the right shape of probability distribution" that applies to the particular case, so as to be able to compute the right answer. Therefore, the Gaussian distribution is chosen not because anybody believes that it really applies, but out of expediency – it is simple to compute. It bypasses any attempt to consider systematics, and it does give some numerical results. These are known by the experts to be imprecise (incorrect even) and should therefore be considered with a pinch of salt (i.e. not to really trust them), so as not to reach the wrong conclusions.

It is highly debatable whether or not the systematic errors on measurements concerning quality control of Irish stout are so reduced by the factory-controlled environment as to be negligible. This was the original use for the so-called "Students t-test", after all. Be that as it may, as this refers to an industrial production process, this certainly does not apply to measurements of human knowledge (this being as far removed from a production line as humanly possible). Similar arguments with those concerning the t-test apply for various other functions used in simple data testing and analyses. The nature and the value of the systematic errors always exceed the scope of such approaches, even when especially careful experimental measurements are concerned.

One should recognise that the statistical significance control in any research is only able to offer a partial image of the real situation [1]. It is quite clear that simple statistical analyses are incapable of answering the complex problems posed by the total experimental errors, which indeed differ from data-point to data-point.

This does not mean that statistical analyses are worthless. On the contrary, they are of immense value, indeed. It is just that they should not be done lightly, but always by experts and within the framework of a much wider Statistical Inference, and the even deeper Scientific Inference.

## 10 Does the Evaluation of the Experimental Results Lead to Right and Verifiable Conclusions or not?

Functions like those mentioned above are statistical in nature, and the great majority assume Gaussian probability distributions. Such simple distributions are intrinsically incompatible with the existence of sizeable "remaining systematic errors" (i.e. non-bias ones). However, when one measures human knowledge, the existence of very large systematics is inevitable, simply due to the complexity of the observable quantity, and the broadness in its definition. Such errors are simply added on top of the statistical ones, and these result to probability distributions wildly different to the normal distributions.

Therefore, even when the use of the aforementioned functions is done properly, their use should be done with extreme caution [9], as there is just no way so as the systematic errors can be factored in the computation of these functions.

It is really remarkable that while it is very rare indeed to see any type of experimental article in Science and Technology without containing some special and meticulous treatment of the systematic errors occurred, on the contrary in Humanities (including Education research), although the systematics are markedly more significant, the norm is to ignore them. (Caveat emptor: However, there are clearly some notable exceptions, namely the research articles by few meticulous researchers). More often than not, just a rudimentary statistical significance check is been performed, and the subsequent hypothesis testing is proceeding without even offering lip service to the existence of all those very significant systematics of all types and sorts. This is, naturally, deeply worrying as it does raise questions as to the validity of the conclusions offered thereof.

## 11 Conclusions and Recommendations

In conclusion, it is patently inappropriate to analyse experimental data simply using Statistical methodology. A proper and thorough analysis of experimental data usually does use some serious Statistical methods, but it should really be extended so as to include errors of each category and type. The final information would then derive from the data analysis, in full awareness of our level of confidence associated with this final information. Within this level of confidence, these final results should be fully verifiable (and, indeed, repeatable) using any alternative experimental procedures. This is the very essence of the Scientific method – which really is the only method to proceed in acquiring new knowledge, with any level of certainty.

In order to extract scientifically correct results, it is simply insufficient to keep using all sorts of simple statistical functions computed via the use of popular software packages, no matter how good these may be. More so, when this is proceeding via the quotation of a series of numerous arithmetic results derived by the use of a plethora of functions (or so-called criteria), without any consideration as to whether or not the conditions for their use are valid in the case concerned.

Finally, there are no shortcuts to a proper data-analysis procedure. Nothing can really substitute real Experimental Inference. No statistical function, or procedure, or methodology, or hypothesis-testing process, can ever come close to satisfying that elusive gold standard of scientific proofing. When adhering to this procedure, every possible effort to minimise systematic errors is first attempted, including bias-corrections. The remaining systematics are subsequently estimated, and (entirely independent to those) the statistical errors are computed separately for each measurement and for each data-point presented. A thorough and uniquely Scientific Inference procedure follows, leading to the derivation of truly valid, supportable, and verifiable results.

## References

1. Ioannidis, J.P.A.: Why most published research findings are false. PLoS Med. **2**(8), e124, 696–701 (2005). http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.0020124
2. Sackett, D.L.: Bias in analytic research. J. Chronic Dis. **32**, 51–63 (1979)

3. Tavakol, M., Mohagheghi, M.A., Dennick, R.: Assessing the skills of surgical residents using simulation. J. Surg. Educ. **65**(2), 77–83 (2008)
4. Cortina, J.: What is coefficient alpha: an examination of theory and applications. J. Appl. Psychol. **78**, 98–104 (1993)
5. Streiner, D.L.: Starting at the beginning: an introduction to coefficient alpha and internal consistency. J. Pers. Assess. **80**(1), 99–103 (2003)
6. Schmitt, N.: Uses and abuses of coefficient alpha. Psychol. Assess. **8**(4), 350–353 (1996)
7. Gigerenzer, G., et al.: On the tyranny of hypothesis testing in the social sciences. Contemp. Psychol. **36**(2), 102–105 (1991)
8. Gigerenzer, G., et al.: The Empire of Chance: How Probability Changed Science and Everyday Life, (Ideas in context vol. 12). Cambridge University Press, Cambridge, New York, Melbourne (1989)
9. Green, S., Thompson, M.: Structural equation modelling in clinical psychology research. In: Roberts, M., Ilardi, S. (eds.) Handbook of Research in Clinical Psychology, pp. 138–175. Wiley-Blackwell, Oxford (2005)

# Data-Mining Possibilities in Blended Learning

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**Abstract.** During our three years' research, we have refined our on-line learning model based on the reflections of students and teachers. After the 3rd year, we examine not only the reflections but also the huge amount of data we collected during the semester. The aim of this paper is to present the data-mining tools we used, the results of our examinations and the next version of our model.

**Keywords:** Blended learning · Data mining · Reflection

## 1 Introduction

On our university (Corvinus University of Budapest), we have developed a group of courses for teaching IT for more than 1000 students effectively. The practical part of the whole compulsory Informatics subject for every business and economics majors (except for Business Informatics major) is hold in blended-learning system. In our final model, we have video-aided online lessons in a Moodle course expanded with flipped classroom-based seminars and gamified scoring method [4–10, 13]. We used this model in the 2016–17 fall semester with approximately 1100 full time and 200 part time students.

As you can see on Fig. 1 our model has three components. We separated the learning content into 4 modules. Every lesson contains videos, textbook, exercises and quizzes. There are no traditional face-to-face seminars but every student has a mentor and has to participate a seminar two times during the semester. On the seminars they have to do collaborative teamwork and solve a complex problem based on the on-line material. On the seminars they have to fill a quiz as well and they get points for the teamwork too.

The evaluation system is mixed. There are gamification elements and also a final exam. During the semester students can gain points by the weekly quizzes, and on the seminars. They also can pick up badges wit high performance on the weekly quizzes by modules and on the seminars as well. There is an extra possibly badge for a homework in connection with the lectures. The total possible number of the badges is 7. With 6 badges they have mark 5 without an exam. In Hungarian system mark 5 is the best, and mark 1 means fail.

We assure the life-ring quizzes. Students have the opportunity to solve these quizzes unlimitedly. There are a large number of similar questions for the same item of knowledge.

30% of the total points can be collected during the semester and 70% on the final exam.

While we use the Moodle system as online learning environment for supporting the courses, it provides us a huge amount of data during the semester with the logs. By the


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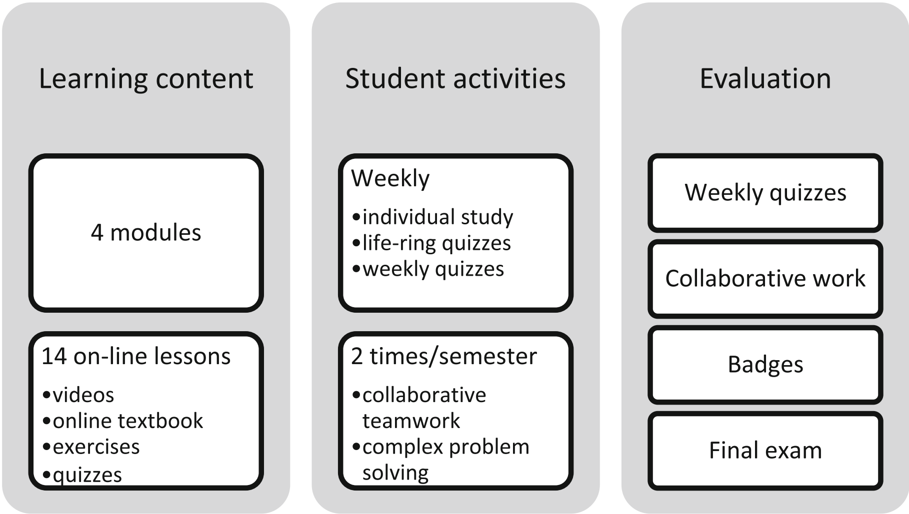


**Fig. 1.** On-line learning model [2]

gamification tools, we have extra information about the students' activity as well: not only about the frequency of their work but also about the quality.

At the beginning of each semester we always ask our students to fill a questionnaire about their preliminary knowledge and IT usage habits as well.

The tools of data mining can give us the possibility to define the key points in students' success absolving the course. We are able to analyze the role of the students' preliminary knowledge and the activities during the semester. We can evaluate our methods for motivating our students. We also can find those students during the semester who need more help.

There are two different courses for full time students. The system is the same but there are some differences in the content according to the students' major.

## 2 Data-Mining

The last decades have seen considerable advances in the data mining, as well as the need to create a standard which would be a guideline to data mining projects. There are two widely recognized methodology: the CRISP-DM (Cross Industry Standard Process for Data Mining) and the SEMMA (Sample, Explore, Modify, Model, Assess). During our research, we followed the CRISP-DM that consists of six main steps which you can see in Fig. 2.

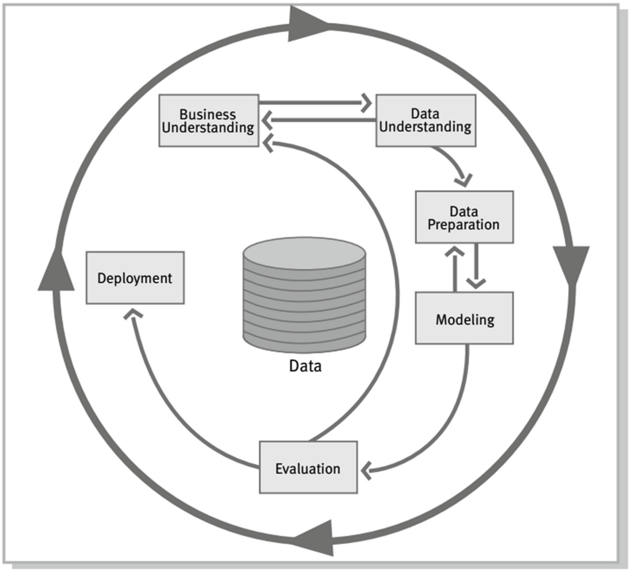


**Fig. 2.** The main steps of the CRISP-DM standard [3]

In knowledge discovery process, it's essential that we use the right method to find the rules of a data set. Depending from the type of the data there are several methodologies for this purpose like classification which is the most common method for data mining projects.

The goal of classification is to separate the attributes into several predefined classes as accurately as possible in the hope that we can make predictions to them or to identify the outliers. During classification, we segregate the records based on the known attributes under analysis, into predefined classes. The resulting criteria are called "labels". The terminology for the algorithms of the classification is "supervised learning". This is due to the fact that during the learning process we know exactly which element of the data set belongs to which class [1].

Various algorithms are available for classification, the ones mostly used are: decision trees, Naive Bayes algorithm and the nearest neighbor rule.

In our study, we focus on decision trees and Naive Bayes procedures.

The decision tree is based on a series of decisions which can lead to the right conclusion. This series of decisions is stored in tree structure. We proceed from the root following the nodes which store the decisions until reaching the leaves of the tree where we can find the predictions about the final decision [1].

With the Naive-Bayes methodology we can estimate the probability of a sample belonging to the predefined class or falling outside [12].

# 3 Our Data-Mining Models

## 3.1 Data

We analyzed the data of one of the courses. There were 367 students from three majors on that course.

As we mentioned in the introduction we had three different kind of data. (1) Questionnaire about the preliminary knowledge (2) Moodle logs about the activity (3) Results: points and badges gained during the semester and points and marks gained in the exam period.

(1) We have 80 attributes from the questionnaire, included questions about the type of the high school they attended, if they had IT certificates or not, detailed questions about different fields of IT whether they studied them or not and how much they know them. 273 students filled the questionnaire out of the 367.
(2) In our teaching model there are a lot of material and activity in the Moodle. There are 14 on-line lessons with videos, online textbook, exercises and quizzes. We have information about the frequency of opening these material and activity from the Moodle log.
(3) We have the results of the weekly quizzes, the points they gained on the seminars (two times in the semester), the number of the badges and the marks they got. There are the so-called life-ring quizzes for practicing. We have the results of these quizzes as well.

## 3.2 Tools

For the models we used the RapidMiner open source application. We chose this software because it's a suitable platform for data preparation, machine learning and model deployment as well. Thanks for its powerful visual design environment it's easy to build predictive analytic models. There are more than 1500 available built-in operations for serving any use case [11].

On Fig. 3, you can see the steps of the data preparation process which are the following:

1. Reading the earlier prepared and cleaned input data set
2. Selecting the attributes to be used in the prediction
3. Setting the role which means the selection of the target variable
4. Validation when we separate our data set into two different groups: one for the training process, one for the testing

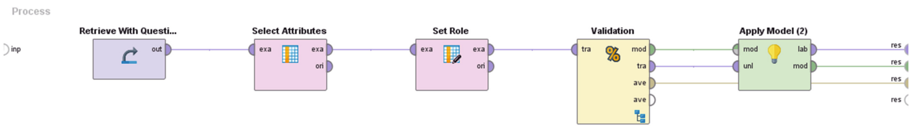


**Fig. 3.** The steps of the data preparation process with RapidMiner application

The training process follows the validation. In this step, we train our model. In the above-mentioned cases, we chose the decision tree approach which requires criterion options like gain ratio, gini index or accuracy. With these options, we can set the partitioning principles which describe a guideline for the decision tree.

During the testing process, we used two operations: The Apply Model on the test data set and the Performance operation for measuring the performance of our model.

One of our goals was to find those students who have difficulties during the course. In order to analyze the performance of these students, we also made a decision tree based model, which in the end helped to predict which students may need help with their studies. To get these results we had to define a new variable which was given as a target attribute in our model. The definition of this variable is the following: those students need help during the semester and the exam period as well whom final grade is below the average. To determine this, we had to calculate the average of the grades which was 2,956. (In the Hungarian education system mark 1 means failing and mark 5 means excellent result.)

In RapidMiner we defined the new attribute with the Generate Attributes operation. You can see the implementation of our newly introduced function Fig. 4.


**Fig. 4.** The implementation of the function which is needed to predict those students who need help

### 3.3 Models

In our research, we made the following predictions with the above-mentioned methodologies:

- Prediction about the final score
- Prediction about the badges gained during the semester
- Prediction about students who need help based on the results of the first quarter of the semester

## 4 Results

### 4.1 Prediction About the Final Score

The accuracy of our model is 67.27% according to the confusion matrix (see Table 1). In the model where we predicted the final scores of the students, the attributes mostly affected the outcome are: the results of the weekly tests during the semester, the gender and the preliminary IT studies and knowledge of the students. Besides these characteristics, the most authoritative attribute was the badges which may be gained from extra tests and homework.

**Table 1.** Confusion matrix of the model for prediction about the final score

| | true 0 | true 1 | true 2 | true 3 | true 4 | true 5 | class precision |
|---|---|---|---|---|---|---|---|
| pred. 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.00% |
| pred. 1 | 0 | 1 | 0 | 0 | 0 | 0 | 100.00% |
| pred. 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0.00% |
| pred. 3 | 0 | 0 | 1 | 3 | 5 | 0 | 33.33% |
| pred. 4 | 0 | 1 | 0 | 8 | 10 | 1 | 50.00% |
| pred. 5 | 0 | 0 | 0 | 0 | 0 | 23 | 100.00% |
| class recall | 0.00% | 33.33% | 00.00% | 25.00% | 66.67% | 95.83% | |

For this above-mentioned reason, we made a prediction about the badges as well which may be acquired during the semester. We will show it in the next point.

To increase the efficiency of our research we performed a modeling, which is based on the Naive Bayes methodology on the previous used data set as well. The synthesis of this model is similar to the synthesis of the decision tree. We just had to replace the Decision Tree operation to the Naive Bayes operation (Fig. 5).

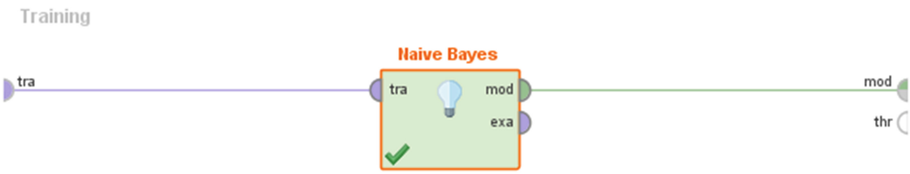


**Fig. 5.** Training the Naive Bayes model

As a result of the Naive Bayes model we got simple distribution functions. These functions show us that in each interval how much chance the students have to get the given grade.

Since we concluded earlier which attributes are significant for the mentioned decision trees. We assessed the distribution functions of the Naive Bayes model for these exact variables, like for example: the gender of the students.

As you can see in Fig. 6 the ratio of males is much bigger among the students who failed (68.5%) than among the students with mark excellent (43.0%).

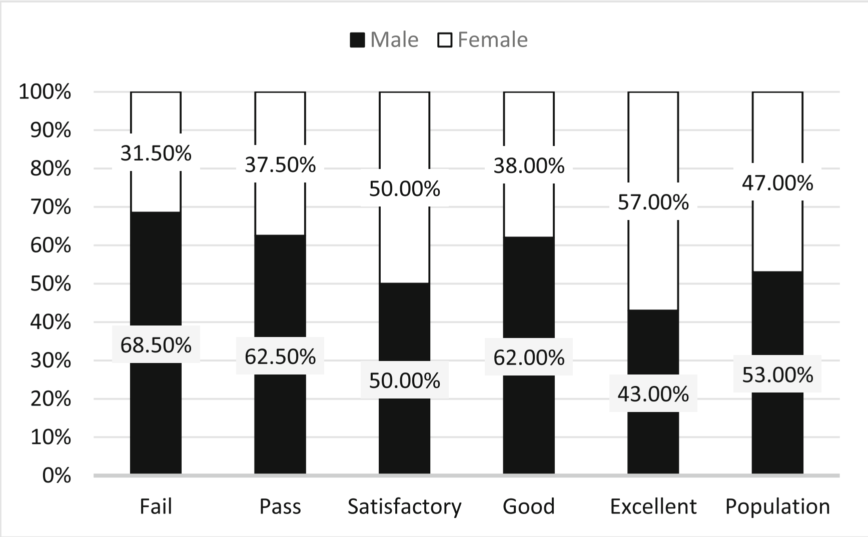


**Fig. 6.** Distribution function of the Naive Bayes model regarding the gender of the students

The above showed result can be explained by the apparent diligence of the female students through the whole semester. But as you can see on the chart, a substantial proportion of the male students gained good results which can be explained by their higher IT knowledge and their dedication.

### 4.2 Prediction About the Badges Gained During the Semester

As a result, it turned out that the most determinative variables of this query are the final score reached from the modules, the results of the quiz written during the practical trainings and the count of the attendances of the students on the life-ring quizzes. In this case, the gender and the preliminary IT knowledge have a bigger effect on the badges as well.

### 4.3 Prediction About Students Who Need Help Based on the Results of the First Quarter of the Semester

We defined students who need help as those students who failed at least ones on the exams. From the third prediction that was based on the results of the first half of the semester it turned out, we can find those students who will need help at the middle of the course.

As you can see on Fig. 7, if a student had less than 18.5 total points in Module2 (out of 24), he or she had problems on the exam. More than half of the students who need help are in this group (51 out of 83) and there are only 6 students in this group who do not need help.

```
Module2_total > 18.500
| Seminar_quize_1 > 4.375
| | Entrance points? > 442: do not need help{Need = 0, Not = 88}
| | Entrance points? ≤ 442
| | | Webdevelopment = was not tought in high school: do not need help{Need = 0, Not = 8}
| | | Webdevelopment = was tought in detail in high school: do not need help{Need = 0, Not = 6}
| | | Webdevelopment = was tought partly in high school
| | | | Multimedia editing = was not tought in high school: need help {Need = 3, Not = 2}
| | | | Multimedia editing = was tought partly in high school: do not need help{Need = 0, Not = 5}
| Seminar_quize_1 ≤ 4.375
| | Entrance points? > 453
| | | Average number of filling weekly quizzes > 1.58: do not need help{Need = 0, Not = 31}
| | | Average number of filling weekly quizzes ≤ 1.58
| | | | Use computer for playing? = Yes: do not need help{Need = 1, Not = 10}
| | | | Use computer for playing? = No: need help {Need = 5, Not = 2}
| | Entrance points? ≤ 453
| | | How much time spent with computer? = Few hours per week: need help {Need = 3, Not = 0}
| | | How much time spent with computer? = More than 4 hours per day
| | | | Seminar_quize_1 > 4.125: do not need help{Need = 1, Not = 8}
| | | | Seminar_quize_1 ≤ 4.125
| | | | | Seminar_quize_1 > 3.625: need help {Need = 11, Not = 1}
| | | | | Seminar_quize_1 ≤ 3.625
| | | | | | Learnt IT by himself/herself? = Yes: need help {Need = 2, Not = 1}
| | | | | | Learnt IT by himself/herself? = No: do not need help{Need = 0, Not = 4}
| | | How much time spent with computer? = Few hours per day: do not need help{Need = 6, Not = 18}
Module2_total ≤ 18.500
| Weekly_quize_II/3 > 5.500
| | Create a table in spredsheets = was tought in detail in high school: do not need help{Need = 2, Not = 6}
| | Create a table in spredsheets = was tought partly in high school: need help {Need = 6, Not = 0}
| Weekly_quize_II/3 ≤ 5.500: need help {Need = 43, Not = 0}
```

**Fig. 7.** Decision tree for finding students who need help

On the other side, if a student had more than 18.5 points out of 24 in the second module and had more than 4.375 points on the quiz written on the first seminar then he or she did not have problem. More than half of the students who do not need help are in this group (109 out of 190) and there are only 3 students in this group who need help.

Those, who are in the group gained more than 18.5 points in the second module but less than 4.375 on the first seminar are in a mixed group. It is more difficult to predict their difficulties. There is a decision point in the entrance points (points gained during the entrance process to the university). Above 453 points they do not need help but below we have only intentions. For example the more they use the computer the less they need help.

## 5 Summary and Future Work

With the help of data-mining as an additional tool we were able to have extra reflection above the traditional ones. In our paper we presented 3 different prediction models.

In the first one we found that the number of badges is the main factor of the mark, but it is not a surprise because 6 badges mean mark 5. It is not true in the other direction because students can get mark 5 on the exam, without the badges as well, but we recognized that there were only a few students do so. It is a confirmation for us that our gamified scoring method managed to motivate the better students work during the semester.

In the second model above the obvious factors (the level of points they earned in different fields) there were some interesting other factors: the count of the attendances of the students on the life-ring quizzes, the gender and the preliminary IT knowledge. Among these factors the number of attendances on the life-ring quizzes shows the diligence of the students.

The most interesting and forward-looking result is in the third model. We found those key elements that help to identify those students who will have problems on the exams at the middle of the semester. With this knowledge we can reach these students through their mentors and offer them extra help during the semester.

We develop our IT courses year by year embedding the reflections from the students and the teachers. From now, we can expand the process using the results of data mining. According to the last year's reflections, we are on the right path but there is a quite wide range of students who need more support to be able to absolve the subject.

In the paper we presented our teaching model and the huge amount of data we can collect during the semester. We presented three data-mining models we built on our data. The first two gave us additional reflections on our work. The third one can be built in our model in the following years.

## References

1. Abonyi, J.: Adatbányászat a hatékonyság eszköze. Veszprémi Egyetem, Veszprém (2006)
2. Baksa-Haskó, G.: Efficiency over 1000 students – the evolution of an on-line course: from e-learning to flipped classroom. In: Auer, M., Guralnick, D., Uhomoibhi, J. (eds.) Interactive Collaborative Learning, Advances in Intelligent Systems and Computing, ICL 2016, vol. 545. Springer, Cham (2017)
3. Chapman, P., Clinton, J., Kerber, R., Khabaza, T., Reinartz, T., Shearer, C., Wirth, R.: CRISP-DM 1.0. Letöltés dátuma: 2017. 03 02, forrás: IBN Corporation (2000). ftp://ftp.software.ibm.com/software/analytics/spss/support/Modeler/Documentation/14/UserManual/CRISP-DM.pdf
4. Clark, R.C., Mayer, R.E.: e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning. Wiley, San Francisco (2011)
5. Falch, M.: A study on practical experiences with using e-learning methodologies and cooperative transnational development methodology. In: LEONARDO DA VINCI Programme (2004). http://www.telecottage.mimoza.hu/domain13/files/modules/module15/13393A0C4647BE39.pdf
6. Garrison, D.R.: E-Learning in the 21st Century: A Framework for Research and Practice. Taylor & Francis, New York (2011)
7. Hsin, W., Huang, Y., Soman, D.: A Practicioner's Guide to Gamification of Education (2013)
8. Idemudia, E.C., Negash, S.: An empirical investigation of factors that influence – anxiety and evaluation in the virtual learning environment. In: Proceedings of the Southern Association for Information Systems Conference, Atlanta, GA, USA (2012). http://sais.aisnet.org/2012/IdemudiaNegash.pdf
9. Mok, H.N.: Teaching tip: the flipped classroom. J. Inf. Sys. Educ. **25**(1), 7–11 (2014). http://ink.library.smu.edu.sg/cgi/viewcontent.cgi?article=3363&context=sis_research

10. Ollé, J.: On-Line tanulási környezetek használatának sajátosságai a felsőoktatásban. In: Nádasi András (szerk.) Agria Media 2008 Információtechnikai és Oktatástechnológiai Konferencia és Kiállítás és ICI-8 Nemzetközi Informatikai Konferencia: WEB 2.0 a hatékony e-learning alapú oktatás. Eger, Magyarország, 27–28 October 2008. EKF Líceum Kiadó, pp. 84–85 (2008). ISBN: 978-963-9417-09-0
11. RapidMiner: A complete platform for predictive analytics. Letöltés dátuma: 2017. 03 10, forrás: RapidMiner 7.3 Data Science Platform (2016). https://1xltkxylmzx3z8gd647akcdvov-wpengine.netdna-ssl.com/wp-content/uploads/2016/12/rm-platform-fact-sheet-12-2.pdf
12. Russel, S., Norvig, P.: Artificial Intelligence. Pearson Education Inc., Upper Saddle River (2003)
13. Sun, P.-C., Tsai, R.J., Finger, G., Chen, Y.-Y., Yeh, D.: What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. Comput. Educ. **50**(4), 1183–1202 (2008). http://www.sciencedirect.com/science/article/pii/S0360131506001874, https://prezi.com/etk6whxypd_f/what-drives-a-successful-e-learning-an-empirical-investigation-of-the-critical-factors-influencing-learner-satisfaction/

# Follow-up on Rubric-Based Assessment of Student Outcomes by Senior-Year Graduation Design Project and Continuing to Improve by Performance Indicator Breakdown-Based Assessment

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**Abstract.** The study is a follow-up on rubric-based assessment of level of attainment of Student Outcomes (SOs) in Environmental Engineering undergraduate education by the senior-year Graduation Design Project (GDP): the focal points are the process of and results from incorporation of additional assessment tools and implementation of "Performance Indicator (PI)-breakdown" to continue improving the SO Assessment and Evaluation (A&E) process. For several consecutive cycles, A&E to define attainment level of total of seven SOs by the GDP gave results below the set thresholds for some of them (SO1, 5, 8), which indicated a discrepancy and a need for improvement in the assessment tools and processes. Accordingly, two remedial actions were undertaken to meet those needs and the SOs were re-assessed. Results of the previous and improved SO A&E process revealed a clear progress in SO attainment addressed by the GDP, from 2014–15 to 2015–16, upon choice and addition of other tools. Yet, those still gave a general sense of deficiencies at SO-level. Therefore, some additional tools were added and the "PI-breakdown"-based approach was implemented. Those informative results are combined successfully with the formerly improved SO A&E process, facilitating attainment of more realistic results and further fine tuning of the SO A&E process.

**Keywords:** Assessment and Evaluation (A&E) · Engineering education
Environmental Management Considerations (EMC) · Graduation design project
Performance Indicator (PI) · Problem/design-based learning
Student Outcome (SO) · Rubric

## 1 Introduction

Environmental Engineering Undergraduate Program (EEUP) [1] is among the 23 UPs of Istanbul Technical University (ITU) currently accredited by the ABET EAC (Accreditation Board for Engineering and Technology, Engineering Accreditation Commission) [2]. More than 50% of the total credits (min. requirement for graduation) offered by the curriculum is comprised of those from the "Engineering Science" and "Engineering


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Design" courses, mainly given in the junior- and senior-years. Compulsory "Engineering Design" courses have a particular significance in the curriculum, since those are meant to serve for improving student attributes related to "Problem-Based Learning (PBL)", in addition to conveying program/content-specific knowledge to the students, as well as develop and sharpen their engineering design skills.

"Graduation Design Project (GDP)" offered in the senior-year, is the final engineering design course of the curriculum, and is designated for summative enhancement of the expected sum of gradually accumulated knowledge and skill-sets of the senior-year students right before graduation. Accordingly, educational objectives of this comprehensive course span over a wide spectrum including but not limited to helping students improve their critical problem-solving skills and decision-making abilities, engage in active and collaborative/cooperative learning and develop self-learning strategies, engage in team-work, structure solutions to real-life problems etc.; all linked to PBL [3]. Those objectives are closely related with the ABET EAC Students Outcomes (SOs) as well, and thus GDP has a significant role in assessing the level of attainment of several SOs by the EEUP.

In order to measure student performance in the GDP course and help determine the effectiveness of the education in developing and/or improving targeted student abilities and learning attributes, a detailed and comprehensive grading rubric was designed by the course coordinators in 2010–11 Spring, and has been in use since then with some modifications [4]. Details of the GDP-specific grading rubric and the overall grading system are given elsewhere [5]. Results of the extensive assessment process run in 8 consecutive semesters between 2010–11 Spring and 2014–15 Fall terms, as well as recommendations for changes in the GDP-Rubric were also reported previously [5 and 6, respectively]. As stated in those studies, the A&E process executed for several consecutive review cycles to define the level of attainment of SOs addressed by the GDP course gave results below the set thresholds for some of them (e.g., SO1, SO5, SO8). Those results indicated a discrepancy and called for a new outlook.

Accordingly, the current study is a follow-up on rubric-based assessment of related SOs by the senior-year GDP, and includes (i) the A&E results from the subsequent 2 runs in 2015–16 Fall and Spring terms, (ii) the remedial action executed by incorporating the newly introduced "*Environmental Management Considerations (EMC)*" into the GDP-specific grading rubric to improve the assessment tool (2015–16 Fall), and (iii) the remedial action undertaken to continue improving the process through implementation of the "*Performance Indicator (PI)-breakdown*" based assessment to the SO A&E process (2015–16 Spring).

## 2 Approach and Tools

### 2.1 The Student Outcomes (SOs) Addressed by the GDP

SOs addressed by the GDP with a relative level of contribution of *"[3]: Emphasized (Assessed and Evaluated)"* are SO1, SO3, SO4, SO5, SO7, SO8, SO11 corresponding to the ABET EAC SOs of (a), (c), (d), (e), (g), (h), (k), respectively.

## 2.2 The Assessment Tools

***Assessments between 2010–11 Spring and 2014–15 Spring terms***

This period covers 9 consecutive semesters during which abilities of 272 senior-year students (210 and 62 in spring and fall terms, respectively) were assessed and evaluated based on their individual- and/or team- performances on their GDP assignments. Tools used during that long period for assessing the level of attainment of the SOs addressed by the GDP are listed in Table 1 (14–15S data & footnotes) and are described below:

- *Tools for SO1, SO5, SO8 A&E: OBEx (Outcome-Based Exam):* specific questions addressing those SOs, which were prepared and asked in the "technical exam" given by the end of each semester.
- *Tool for SO3 A&E: GDP-Rubric:* in the first 4 A&E runs, results from OBEx questions were used, whereas in the next 5 runs, assessment was carried out by using scores from the relevant parts of the GDP-Rubric.
- *Tool for SO4 A&E: SO4-Rubric:* an analytic rubric comprised of 4 PIs, which was designed by the assigned faculty (SO4-coordinator) for assessing students' performances in team-work.
- *Tool for SO7 A&E:* two analytic rubrics (W and O), each comprised 6–8 PIs, which were designed by the assigned faculty (SO7-coordinator) for assessing students' abilities in written and oral communication.
- *Tool for SO11 A&E:* Drawings: scores collected by the student-teams from the "Technical drawings" chapters of their GDP final reports were used.

## 2.3 The GDP-Specific Grading Rubric

As stated previously, a detailed and comprehensive grading rubric was structured and implemented by the course coordinators in 2010–11 Spring specifically to assess student performance on all features of the GDP assignment. Details of the rubric and the overall grading system are given elsewhere [5]. Briefly, main sections of the rubric were related with "content quality and technicalities (18%)", "process and system design (60%)", "cost analysis (18%)", and "time and project management (4%)". GDP final reports including detailed entries at each of those main- and related sub-sections were assessed by the team-supervisors, the GDP coordinators and the jury members. Additionally, individual student performances (e.g., contribution to progress of project and team-work, presentation skills during defense, scores in technical exam, etc.) were also assessed [6]. Various sub-sections of the GDP-Rubric included queries related with the SOs addressed by the GDP, hence scores from those sections were used in SO A&E. Accordingly, the GDP-Rubric was used both for grading and for SO A&E in 9 consecutive semesters between 2010–11 and 2014–15 Spring terms.

## 2.4 1st Remedial Action to Improve the Assessment Tools (2015–16 Fall)

ABET EAC's Program Criteria for "Environmental Engineering Programs" have been revised recently (*effective starting from 2015–16 and further*) by addition of, e.g., the requirement that "the curriculum must prepare graduates…….. to design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts" [7]. Those new entries of "*Environmental Management Considerations (EMC)*" were rapidly incorporated into the ITU EEUP curriculum in compliance with accreditation requirements and included in the GDP assignments as of 2014–15 Spring term [8]. The student-teams included their work on EMC in their final reports [8], yet their performance on completion of those new tasks were not assessed explicitly since the EMC were not introduced to the GDP-Rubric in 2014–15 Spring term [4–6, 8].

The GDP-Rubric was initially designed as comprehensive as possible to meet the needs in 2010–14 [4], however revisions in the course called for improving the rubric as well by inclusion of the relevant A&E tools (performance indicators and vectors) addressing assessment of student performance regarding the new EMC titles. Accordingly, improved version of the rubric (GDP-iRubric) was recommended to be used for grading and SO A&E in the next run [6] and implemented in 2015–16 Fall term.

### 2.5 2nd Remedial Action to Improve the A&E Process (2015–16 Spring)

To provide a better insight to the SO A&E and enable determining at which particular aspects the senior-year students have strengths and weaknesses, it was required to provide more elaborate and informative A&E process. Accordingly, another remedial action -namely the "*PI-breakdown*" based assessment- was implemented in Spring 2015–16 and the instructors were asked to assess students' performances both by using the GDP-iRubric and other assessment tools, as well as the detailed analytic rubrics specifically designed for each SO addressed by the GDP.

## 3 Results

As stated above, for several consecutive review cycles, the A&E process to define level of attainment of seven SOs by the GDP gave results below the set thresholds for some SOs (SO1, SO5, SO8). Results of overall level of attainment of some of those SOs are presented in Fig. 1. On the other hand, considering the features, objectives, content, and operation of the GDP, and the final product –the report prepared by student teams-, as well as recent addition of the new EMC titles both to the assignments and to the GDP-iRubric; it seemed contradictory obtaining student performances below the threshold in those SOs. Thus, it became apparent that the aggregative measures of students' performances were required to be broken down to address individual SO-related PIs.

As seen in Fig. 1, even with the previous and improved assessment tools and results in hand, it was still not possible to identify at which particular dimensions, in other words –*PIs*- comprising the explicit details of the SO A&E scheme, that the senior-year students seemed to be performing below expectations. Therefore, it was strongly recommended to implement the "*PI-breakdown*" based assessment approach as of 2015–16 Spring term in the SO A&E process run through the GDP.

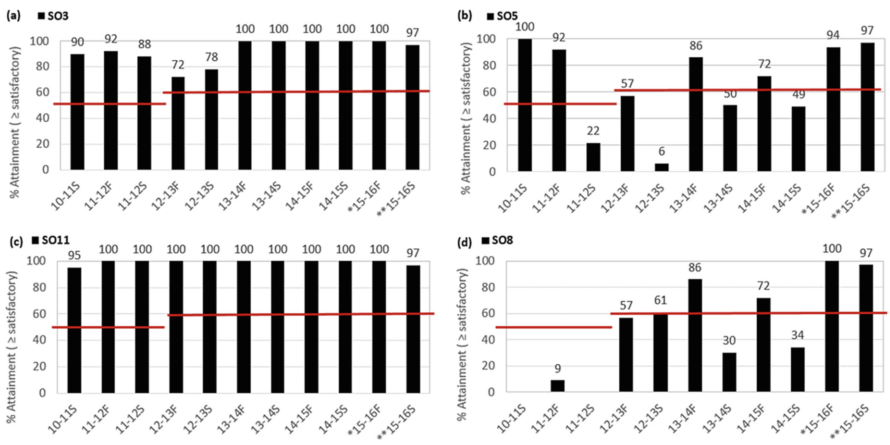


**Fig. 1.** Overall assessment of level of attainment (at or above "satisfactory") of SO3 (a), SO5 (b), SO11 (c) and SO8 (d), and by the GDP in 11 consecutive semesters between 2010–11 Spring and 2015–16 Spring terms. Horizontal lines show the set thresholds. See Table 1 for the additional assessment tools used in *2015–16 Fall and **2015–16 Spring terms

**Table 1.** Assessment plan and comparative results showing the level of attainment of the related Students Outcomes (SO) by the GDP (2014–15 Spring, 2015–16 Fall)[a–h] and recently added assessment tools (2015–16 Spring)[i]

| | % Level of Attainment[a,b] | | | | | | | | Assessment Tool USED | | Assessment Tool ADDED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | U | | D | | S | | O | | | | |
| SO# | 14-15S | 15-16F | 14-15S | 15-16F | 14-15S | 15-16F | 14-15S | 15-16F | 14-15S[c,f] | 15-16F[d,e,g,h] | 15-16S[i] |
| SO1 | 40 | 0 | 11 | 31 | 40 | 19 | 9 | 50 | OBEx | OBEx | SO1-Rubric |
| SO3 | 0 | 0 | 0 | 0 | 9 | 25 | 91 | 75 | GDP-Rubric | GDP-iRubric[d] | SO3-Rubric |
| SO4 | 0 | - | 0 | - | 6 | - | 94 | - | SO4-Rubric[f] | Survey[g] | SO4-Rubric |
| SO5 | 11 | 0 | 40 | 6 | 38 | 75 | 11 | 19 | OBEx | OBEx | SO5-Rubric |
| SO7 | 0 | 0 | 0 | 0 | 9 | 19 | 91 | 81 | SO7-Rubric *(Oral)* | SO7-Rubric *(Oral)* | SO7-Rubric *(Written)* |
| SO8 | 32 | 0 | 34 | 0 | 19 | 25 | 15 | 75 | OBEx | GDP-iRubric[h] | SO8-Rubric |
| SO11 | 0 | 0 | 0 | 0 | 9 | 0 | 91 | 100 | Drawings | Drawings[e]+ OBEx[e] | SO11-Rubric |

a-Number of senior-year students assessed in 2014-15 Spring (14-15S) and 2015-16 Fall (15-16F) terms: 47 and 16, respectively; b-SO assessment performance vectors: U: Unsatisfactory, D: Developing, S: Satisfactory, O: Outstanding; c-Tools used (before and) in 14-15S: "OBEx"- Outcome Based Exam, "GDP-Rubric"- Grading rubric for GDP, "SO4 and SO7"-Rubrics specific for the related SOs, "Drawings"- Technical drawings chapter of GDP final report; d-Additional/improved tools used in 15-16F: "GDP-iRubric"- based on overall grades; e-Additional/improved tools used in 15-16F: sum of scores obtained from (i) question asked in OBEx (60%) and (ii) technical drawing chapter of GDP final report graded in the GDP-iRubric (40%); f-Scores given to each student by the Advisory Team in the SO4-Rubric; g-Mini survey (4 questions) given to senior-year students at OBEx; h-Additional/improved tools used in 15-16F: sum of scores obtained from "Environmental Management Considerations" and "Cost Analysis" chapters of GDP final report (graded in the GDP-iRubric); i-Additional/improved tools recently recommended and used in 15-16S: rubric-based assessment of SOs with PI-breakdown based approach

Results of the previous [4, 5] and recently improved [4, 6] SO A&E process run for the GDP are presented in Table 1 for the 2014–15 Spring and 2015–16 Fall terms, together with the assessment tools used. Those results revealed a clear improvement in the overall level of attainment of the SOs addressed by the GDP course from 2014–15 Spring to 2015–16 Fall, upon selection and use of alternative tools. Yet, those are still giving a general sense of deficiencies in students' performances at SO-level. A genuine picture of the relevance, accuracy, and utility of selected assessment tools was essential. Those deficiencies were overcome by implementation of the "*PI-breakdown*" based assessment in Spring 2015–16. The A&E system included detailed assessment of the students' abilities and attributes corresponding to each specific PI of each SO, assessed in accordance with four performance vectors and specific performance descriptors comprising the detailed analytic rubrics specifically designed for each SO (Table 1).

Informative results of the comprehensive PI-breakdown based SO A&E for selected SOs (SO3, SO5, SO8, and SO11) are given in Fig. 2 for the 2015–16 Spring term.

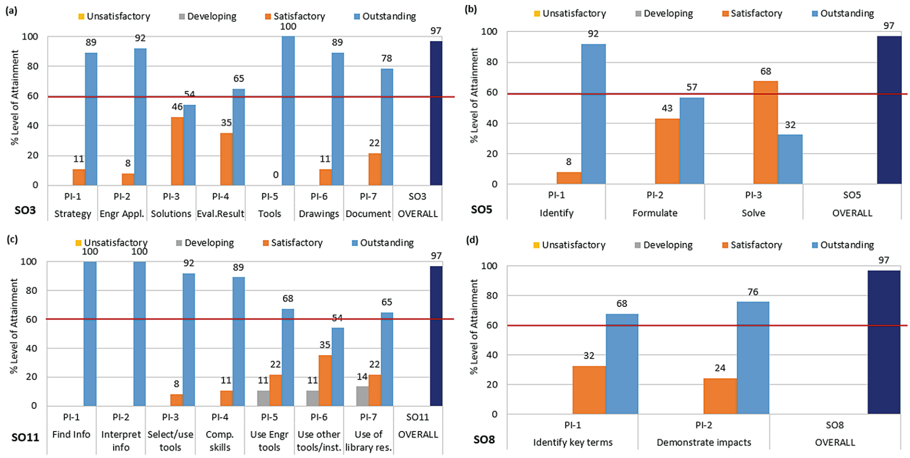


**Fig. 2.** Comparison of overall (at or above "satisfactory") and PI-based (with performance vector details) assessments of level of attainment of SO3 (a), SO5 (b), SO11 (c) and SO8 (d) by GDP in Spring 2015–16. Horizontal lines show the designated threshold. See Table 1 for the additional assessment tools used in Spring 2015–16

The recently recommended "*PI-breakdown*" based assessment facilitated attainment of more realistic and meaningful results. Comparative evaluation of the A&E results showed that all related SOs were attained at levels above the set thresholds (Fig. 2). Moreover, the PI-breakdown enabled determining the particular performance indicators, at which students' abilities might be improved further (e.g., PI-6 of SO11, or PI-2 of SO5, Fig. 2). Those improvements were considered to be not only because of increase in student performances, but also due to implementation of the new tools and the *PI-breakdown* based assessment approach.

## 4 Conclusions and Recommendations

The study exemplifies the Continuous Improvement (CI) Strategy of the ITU EEUP through the educational quality assurance actions taken in recent years in the senior-year Graduation Design Project (GDP) course. SO A&E results from several previous cycles indicated a discrepancy and called for a new outlook. Accordingly, appropriate remedial actions were successfully implemented in 2015–16 Fall and Spring terms and the results have already been obtained. The GDP A&E Team at the ITU EEUP has combined those informative results from the recently implemented "*PI-breakdown*" based assessment with the formerly improved SO A&E process [5, 6]. By this way, a much comprehensive evaluation has become possible, which also enables further fine tuning of the A&E process.

Moreover, "*suggestion for changes*" offered by the GDP A&E team, as well as "*recommendation for changes*" outlined by the SO-coordinators based on the informative and comprehensive results of the PI-breakdown based assessments have already been communicated to the related responsible bodies (i.e., Dept. Administration, Curriculum Development Committee, Accreditation Coordination Committee, etc.) for further discussion and evaluation prior to be directly implemented in the next run (course-level "*remedial action decisions*"), or to be communicated to the higher administrative units for discussion and approval (curriculum-level "*remedial action decisions*").

## References

1. ITU-EED, Istanbul Technical University, Environmental Engineering Department official web-site: Accreditation. http://www.cevre.itu.edu.tr/en/accreditation/abet
2. ABET official web-site. http://www.abet.org/, Find an ABET-Accredited Program. http://main.abet.org/aps/AccreditedProgramsDetails.aspx?OrganizationID=884&ProgramIDs=
3. Duch, B.J., Groh, S.E., Allen, D.E.: The Power of Problem-Based Learning. Stylus Publishing LLC, Herndon (2001). ISBN 978-1579220372
4. ITU EEUP GDP-Grading Rubric. http://www.cevre.itu.edu.tr/en/accreditation/abet#archive, ITU EEUP GDP-Grading iRubric. http://www.cevre.itu.edu.tr/en/accreditation/abet#docs
5. Yangin-Gomec, C., Kose-Mutlu, B., Dulekgurgen, E., Ozturk, I., Tanik, A.: Development and application of a rubric specific for the senior-year graduation design projects for assessing learning outcomes. Iberoamerican J. Proj. Manage. IJoPM **7**(1), 47–61 (2016). ISSN 2346-9161
6. Dulekgurgen, E., Karahan Özgün, Ö., Yangin-Gomec, C., Unalan, C.: Case study on rubric-based assessments for senior-year Graduation Design Project and recommendations for improving the assessment tools. In: ICEILT, International Congress on Education, Innovation and Learning Technologies, Oral presentation - Full Text, in Proc. of ICEILT2015, Granada-Spain, 21–23 September 2015 (2015). ISBN 978-84-944311-3-5
7. ABET EAC Accreditation Criteria, pp. 12–13 (2015, 2016, 2017, 2018). http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf
8. Dulekgurgen, E., Karahan Özgün, Ö., Yuksek, G., Pasaoglu, M.E., Unalan, C., Bicer, O.B., Cetinkaya, Z., Isik, I., Oner, B.E.: A final touch for the environmental engineering students at the onset of their profession: senior-year graduation design project – case study for 2014–2015. Int. J. Eng. Pedagogy (iJEP) **6**(2), 23–29 (2016)

# Evaluation of International Master Thesis in the Program "Entrepreneurs for Tomorrow"

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**Abstract.** The project "Entrepreneurs for Tomorrow" aims to establish a new Master program for Sustainable Entrepreneurship in the Volga Region (Russian Federation). The program E4T has been already running for two and a half years in three main cities in the Volga Basin, (Nizhniy Novgorod, Samara and Saransk). Its main objective is to contribute significantly to a sustainable economic development of this region. This research focuses on the aspects of evaluation of international Master thesis in the program "Entrepreneurs for Tomorrow" within the framework of TEMPUS IV grant. The authors have developed a system of Master thesis's evaluation and worked out a check list (an evaluation grid), which can be used as a basis for comprehending the criteria of marking the final thesis. The purpose of this work is to make master students' outcomes assessment objective and accurate.

**Keywords:** Outcomes assessment · Master's theses assessment Entrepreneurs for Tomorrow

## 1 Introduction

The ongoing project "Entrepreneurs for Tomorrow" has been launched as a new Master program for Sustainable Entrepreneurship in the Volga Region (Russian Federation). It has been already running for two and a half years in three main cities in the Volga Basin, (Nizhniy Novgorod, Samara and Saransk). Its main objective is to contribute significantly to a sustainable economic development of this region at grassroots level with an important emphasis on sustainable development (people-planet-profit). The students who are involved into the program have to develop essential skills how to set up a new company or how to work successfully in the growing number of Small-and-Medium Enterprises (SMEs) in the region [8].

The main task of the students within the master program is to write and to defend a master thesis in the English language on one of the most important issues of sustainable entrepreneurship in the Volga Basin. Such Master thesis is an original independently done research, which analyses social work problems and searches for their solutions. The purpose of the thesis is to enable Master's Degree students to acquire deeper


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knowledge, understanding, abilities and attitudes in the context of the program of study. The thesis should be finished at the end of the program and offers an opportunity to advance and improve knowledge acquired in previous studies and during this program.

## 2 Project Description

### 2.1 International Master Thesis: Content Requirements

A Master Thesis qualifying for a Master degree in the framework of the program "Entrepreneurs for Tomorrow" is supposed to be based on the original investigation of the student and provide a solution to a specific unresolved economic problem existing in the Volga region, demonstrate critical judgment, as well as familiarity with research methods and relevant literature in the chosen field of study.

To fulfill that task, the program's curriculum envisages that 4–5 thesis seminars which take place during the fourth semester of study. At the thesis seminars students grapple with problems they face when preparing their master theses with the supervisors of the program. Innovative mobile research seminars help students to modify their approach to writing of their master theses. They also provide students with knowledge of newest theoretic developments in international studies, as well as with mastering of new research methods.

Students of the Master program for Sustainable Entrepreneurship in the Volga Region choose their Master thesis topic from the list which is suggested by the members from Consortium institutions. The topic should be closely related to sustainable economic development of the Volga region and entrepreneurship in the Volga Basin. The Specific research topic is formulated after discussions between student and thesis' Senior supervisor or co-supervisor. Student can suggest her/his topic as well, in such a case, she/he has to discuss it with both supervisors, if the topic is accepted it should be approved by the Consortium institutions. The main requirements for the topic, as is customary, are relevance, scientific theoretical and practical significance, and novelty [8].

### 2.2 International Master Thesis: Structure Requirements

Nowadays there is a great variety of Methodological guidelines for writing and defending Master theses available on many European and American Universities official sites [1–7, 10]. These guidelines are, however, for their internal use only and are not able to satisfy all regulations existing in this or that particular country or university. That is why we specify certain aspects of our project requirements.

First of all, an international Master thesis must be written in English and followed by an abstract in Russian. The abstract is a concise and accurate summary of the research described in the document. It states the problem, summarizes the Thesis aims, methods of investigation, specific research results and most significant findings, major conclusions and recommendations, research implications for further research and/or professional practice.

In general, Master thesis should be 60–70 pages long, the main part or the body of the thesis may consist of two or three chapters or sections and as many or few subsections as the author feels are necessary. Other important aspects of preparation of international Master thesis in the program “Entrepreneurs for Tomorrow” within the framework of TEMPUS IV grant have already been discussed [9].

### 2.3 Thesis Supervision

Master’s Degree students work under the supervision of two members from Consortium institutions, one being from a European university (who acts as a Senior supervisor) and another from a Russian university (a co-supervisor). The Senior supervisor is the primary contact person of the students during the research and writing stages. The Senior supervisor is expected to help students refine their research topic and methodology; to make sure that students prepare a chronogram in which different tasks and deadlines are clearly indicated; to help students decide what sources and literature should be used and what kind of information students should obtain from there; to offer students advice in the analysis and interpretation of the collected data; to review students’ work regularly and provide him/her with feedback to improve their theses [8].

Co-supervisors read the complete thesis as well as the draft and final thesis proposals. They occasionally provide feedback during research and writing process; however, this is not required and is necessary to be approved by the main supervisor. At the same time, both supervisors attract students’ attention to what exactly will be assessed at the final stage.

### 2.4 Thesis Evaluation and Assessment

Focusing on the assessment of Master’s theses, in our program we pay attention on the one hand to general assessment principles, and on the other hand on special features of different types of research. As the overall grade of a thesis in this country has always been based on an overall consideration (in other words, the grade of a thesis was not necessarily the numerical average of the different evaluation areas) we stress that assessment of an international thesis should be based on certain criteria. For this purpose, an assessment grid has been worked out and is being tested at the moment [9].

It is important that thesis supervisors familiarize students with the suggested Grid for Master’s Thesis Evaluation as soon as they start working on the master’s thesis (see Table 1). The general assessment criteria adopted for the program E4T cover the following issues: objective and main question; methodology; analysis; structure and design; use of language; conclusions and recommendations; relevance, added value and originality; process; defense.

Completing the assessment grid may be useful for the examiners, also in case of possible disputes.

In drawing up this grid, it was a conscious choice not to determine the relative weights of the various criteria. Obviously, the questions under C (and D) have larger weights.

It is suggested that examiners should complete sections A to D while reading the thesis; E only needs to be assessed by the supervisor. As only F needs to be completed during the defense, this should enable the examiners to reach a decision on a final mark quickly [8].

**Table 1.** Assessment grid

| Criteria | Assessment – special comments (+/−) |
|---|---|
| (A) Formatting | |
| Did the student meet the formatting requirements? | |
| Have the references been made in a consistent way? | |
| (B) LANGUAGE | |
| Language and writing style: is the language used sufficiently clear, fluent, concise and vivid? | |
| Have the ideas and problems been expressed in legal terms? | |
| Is the legal terminology correct? | |
| Is spelling correct? | |
| (C) CONTENT | |
| (1) Research question and methodology | |
| Is the research question legally relevant? | |
| Is the research question original? | |
| Does the student manage to state the problem clearly and unambiguously, and to convey the relevance of the research to non-specialist readers? | |
| (2) Design and structure | |
| Are the design and the structure logical (in view of the research question, research methodology; guiding principles)? | |
| Have the applied concepts and choices with regard to structure been clearly explained? | |
| Is the conclusion linked to the research question? | |
| (3) Content | |
| Have the sources been analyzed in an analytical and synthetic manner? | |
| Does the student write in a sufficiently concise manner? (adequate depth, but without superfluous passages)? | |
| Are there no (substantial) errors? | |
| Does the student show sufficient creativity? | |
| Has the right balance been struck between a factual description and the student's own analyses and insights? | |
| Does the student manage to situate the research in a wider context; is he/she able to generalize or suggest directions for further research? | |
| Has the research question been answered? | |

(*continued*)

**Table 1.** (*continued*)

| Criteria | Assessment – special comments (+/−) |
|---|---|
| (4) Critical skills | |
| Does the student display a personal motivation/opinion (clearly distinguished from other opinions?) | |
| Does the student demonstrate critical reflection upon sources and methods? | |
| Has the student developed a well-reasoned personal position? | |
| (D) SOURCE | |
| Does the student refer to a sufficient number of sources? | |
| Are the sources relevant and of a sufficient quality (i.e. appropriate for answering the research question)? | |
| Did the student engage in an exhaustive examination of sources, if feasible; if not, can the selection applied be justified? | |
| (E) PROCESS AND AUTONOMY | NOTE: To be assessed by the supervisor |
| Did the student display a sense of initiative, i.e. did her/she not remain passive? | |
| Did the student establish a clear work plan and did he/she manage to stick to it? | |
| Was the student well-organized in the research process? | |
| Did the student come up with creative solutions to any problems he/she encountered? | |
| Did the student show a good balance between working autonomously and following advice? | |
| (F) ORAL PRESENTATION AND DEFENCE (NOTE: = is also a plagiarism check) | NOTE: Carries little weight, can raise or lower marginal grades by max. 1 or 2 points |
| Did the student give a good oral presentation? (posture, language use and articulation, eye contact, timing, etc. …) | |
| Was he/she able to discuss aspects of the research (e.g. justify choices made, demonstrate relevance, highlight key points, etc.…) | |

## 3 Conclusion

A Master Thesis qualifying for a Master degree in the framework of the program "Entrepreneurs for Tomorrow" should be based on original investigation of the student and provide a solution to a specific unresolved existing in the Volga region, demonstrate critical judgment, as well as familiarity with research methods and relevant literature in the chosen field of study. It is important that a Master's thesis should be assessed objectively and accurately. To clarify how a thesis is assessed Master's Degree students should be familiar with the assessment grid which has been introduced in the framework of E4T program.

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## References

1. Babbie, E.: The Practice of Social Research, 13th edn. Thomson Wadsworth, Belmont (2011). 586 p.
2. Guidelines for Master's thesis. University of Canterbury (2015). 10 p. http://www.canterbury.ac.nz/ucpolicy/GetPolicy.aspx?file=Masters-Thesis-Work-Policy-And-Guidelines.pdf. Accessed 14 Dec 2016
3. Guidelines for the composition of essays, Master's theses, research Master's theses and dissertations. Katholieke universiteit Leuven (2014). 42 p.
4. Guidelines for writing a Master thesis exposé (2012). 5 p. Universität Wien. https://sts.univie.ac.at/fileadmin/user_upload/dep_sciencestudies/Completion_Master/I01_expose_guidelines.pdf, Accessed 12 May 2016
5. Guidelines for writing academic research proposals and theses. Handbook. School of Hospitality and Tourism, Kenyatta University (2012). 22 p. http://www.ku.ac.ke/schools/graduate/images/stories/docs/hospitality_guidelines.pdf. Accessed 13 Jan 2016
6. Hayo, B.: Guidelines for writing a Master's thesis. Marburg, School of Business & Economics, (2015). 7 p.
7. Helgren, J., Parker, D.: Writing Theses and Dissertations. Claremont Graduate University. http://www.cgu.edu/pages/880.asp. Accessed 25 Dec 2015
8. Lopukhova, Y., Suchkov, D.: Aspects of Preparation and Evaluation of International Master Thesis in the program "Entrepreneurs for Tomorrow" in the Framework of TEMPUS Project. New Strategies for Learning Activity Assessment (Scientific local and wide-spread propagation electronic publication), Samara, Russia, pp. 242–252 (2016)
9. Makeeva, E., Spaubeck, J.: International Master Thesis: Structure and Content Requirements in the framework of the program "Entrepreneurs for Tomorrow" (TEMPUS IV Project) (Scientific local and wide-spread propagation electronic publication), Samara, Russia. pp. 222–229 (2016)
10. Teekkari, T.: Master's Thesis Guide. University of Oulu, Department of Communications Engineering (2012). 35 p.

# Knowledge Management and Learning

# Conceptual Modelling: Common Students' Mistakes in Visual Representation

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**Abstract.** Knowledge based systems' design requires the developer's advanced analytical skills. The efficient development of those skills within university courses needs a deep understanding of main pitfalls and drawbacks, which students make during their analytical work in form of visual modeling. Thus, it was necessary to hold an analysis of 5-th year students' learning exercises within courses of "Intelligent systems" and "Knowledge engineering" in Saint-Petersburg Polytechnic University. The analysis shows that both lack of system thinking skills and methodological mistakes in course design cause the errors that are discussed in the paper.

**Keywords:** Knowledge based systems · Knowledge engineering
Students' errors · Visual modelling · Intelligent systems

## 1 Introduction

Increasing infrastructure complexity has affected the role of nearly all IT professionals, creating the need for new skillsets, including the ability to analyze data and knowledge for effective business solutions. We witness the evolving role of the modern IT professional in today's technology-driven business environment. While most IT professionals are at least some degree confident in their ability to provide such advice, more preparation is needed to feel completely confident. The paper is aimed at describing of our attempts to train the analytical and structuring abilities of future IT-professionals.

Courses "Intelligent Systems" and "Knowledge Engineering" are interdisciplinary and they focus on first and second year master students of IT specialisation. Both courses are aimed at the design and software implementation of intelligent systems. These processes are impossible without the important stages – subject knowledge acquisition and conceptual structuring, as we are talking about the systems based on knowledge (this applies to knowledge management systems, expert systems, et al.) [1]. IT-professionals need not only proficiency in software development, but also system thinking and

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analytical skills. Analytical skills are the ability to acquire, elicit, gather, visualize and structure information in details.

These proccesses require knowledge codification and representation e.g. in the form of conceptual models. The tools that can be used for such modeling are mind maps [2], concept maps [3], frames [4] and other tools [5, 6].

The main feature of the conceptual modelling is high requirements to their developers, which include advanced analytical and communicative skills, as well as the ability to generalize information [7]. This is a reason why the process of creating knowledge bases is a labor-intensive, expensive and still poorly formalized process: everything heavily depends on the analyst skills.

However, the conceptual models can also be used to assess students' knowledge in various fields, to determine the capabilities, and to identify problems in the analytical work. Identification and analysis of personal analytical abilities is also important because it affects the success of learning and of professional work. In addition, this analysis helps to improve the course on knowledge engineering, and system-analytical thinking training programs [8].

This paper summarizes the research on knowledge structuring analysis errors within the course "Intelligent Systems" and "Knowledge Engineering" for first year students of master's program "Software Engineering" at the St. Petersburg Polytechnic University. One of the authors has been delivering these courses for more than 20 years. Forty-seven students' works were analyzed in the fall semester of 2016, each of which includes several conceptual models in the form of mind and concept maps. Students develop the skills and competencies of the knowledge engineer's work on the pre-computing stage of intelligent systems' development. At the end of the course they perform a number of individual visual structuring assignments in the form of e-portfolio consisting of 10 visual models (mind-maps, concept maps, flowcharts, etc.).

## 2 About Mind Maps and Concept Maps

Mind Maps are widely used to display the conceptual structures in teaching [8], in the design of software systems [9, 10], in business applications [11] and in a wide range of other areas [12]. Their peculiarity lies in the fact that the main object of study is located in the center of the map as a basic concept, and from the center main areas of consideration branch out firstly, and then further nodal structure branches out [2]. These maps can be used as a first draft to the expert knowledge representation model.

An example of the mind map is given in Fig. 1.

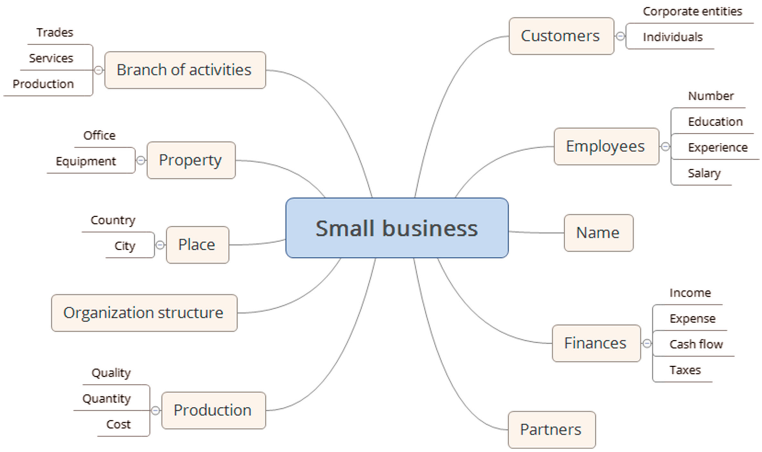


**Fig. 1.** Example of mind map

The rules for constructing such maps are quite simple:

- use a different font-size when displaying the concepts of different levels;
- use color to highlight branches or levels;
- include visual images to increase the expressiveness of mind maps.

These maps development requires system-analytical thinking skills, cognitive ergonomics laws' knowledge and the ability to express thoughts figuratively. Thus, the mind map in Fig. 1 contains several typical errors and omissions:

1. the first level contains too many objects, making it difficult to perceive;
2. these objects have different levels of generality, they are too heterogeneous;
3. the branches have different circumstantiation depth;
4. images and color, which are important for mind maps, are not used.

In general, the students begin to understand the peculiarities of radiant or hierarchical thinking after third-fourth attempt with strict error analysis feedback.

If mind maps show the connection and the tree structure of arbitrary fragments of knowledge, the concept maps allow to consider the subject area deeper and to include relations between concepts. Such conceptual map (c-maps, c-graphs) are composed of nodes and named directed relations or links connecting these nodes. The relations can present different types, such as "is-a", "has property" etc. The concepts and relations are universal for a class of subject domain. Therefore, any development of a c-map involves analysis of the structural interaction between the individual concepts of the subject domain. A concept map is presented as a graph whose nodes represent concepts and whose named directed arcs, connecting the nodes, represent relationships.

For the first time the c-maps were offered by Novak at the beginning of the 70s. [13] in the study of children's thinking and the first scientific concepts formation. This study used the ideas of Ausubel [14] on the formation of conceptual thinking. C-maps are supposed to be an effective tool for human conceptual system modelling.

Visual specification in the form of conceptual maps are widely used in training systems (e-learning) and traditional teaching [15], as well as for modelling enterprise knowledge bases [16].

In the simplest case, their design requires [3–13]:

- definition of context by asking a specific focus question, defining the main theme and the border of the c-maps;
- allocation of basic concepts of the subject domain (usually about 15–20 concepts);
- building relationship defining the interactions of main concepts;
- the map adjustment – refining and removing unnecessary links and contradictions.

"Good" c-map is usually ready after 2–3 iterations. Typical shortcomings are:

- using whole sentences instead of individual concepts in the node;
- using "linear" map (with long chains of single nodes);
- redundancy of intersecting relations;
- superfluity of concepts;
- incorrect relation's type definition.

It is possible to design a c-map on paper, on the board, in any graphic or text editor, but no days the best way is using special freely available online tools like http://cmap.ihmc.us/ IHMC CmapTools [17].

An example of a c-map is presented in Fig. 2, describing a part of an education system developed within the System Project of Moscow [18].

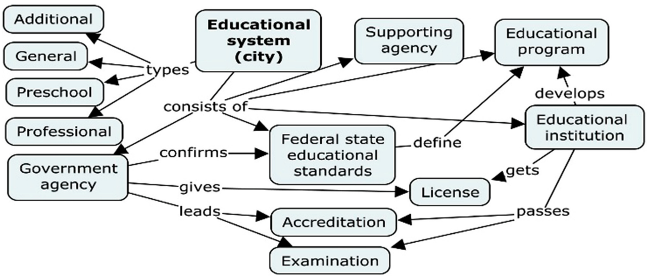


**Fig. 2.** An example of a concept map

## 3 Common Mistakes in Mind Mapping

Analyzing the students mind maps we picked out several groups of typical repetitive mistakes. The first group (conceptualization errors) refers to the mind maps' design process. Students were given the task to create the maps, generalizing knowledge from one of the books from the list of literature for the course "Intelligent Systems".

The difficulty was caused by the wrong level allocation. An omission of several levels of conceptualization was one of the most common errors. It looks like the usage of purely associative relations that cannot be established by outside observer. An example of this illustrated in Fig. 3, where each of the concepts of the first level, especially the "Uncertainty" and "Action", could not be directly related to the central concept.


**Fig. 3.** Typical mind map's error: the conceptualization levels' passing

More general concept, for example, "Application", had to be placed between "Artificial Intelligence" and "Action" concepts. It would include others also.

In addition, students often used too specific terms in the first conceptualization level, though they had to use ones that are more general.

In Fig. 4 first-level concepts "What is necessary for the implementation of knowledge management" and "Key positions" are too specific.

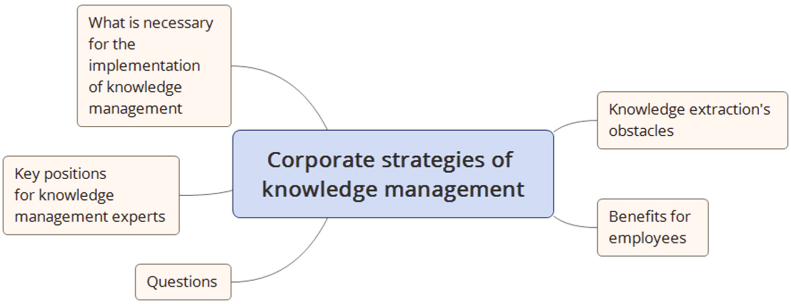


**Fig. 4.** Typical mind map's error: too specific term at the first level

In addition, sometimes the students used on the first conceptualization level terms which meaning and relations are not clear without specific domain knowledge. For example, the central concept "computer vision" was linked with concepts of the first level: "Camera types", "Smooth surfaces and their contours", and "External elements". Their relations will be clear only to a person familiar with this field.

The second group of mistakes – generalization errors, where formal generalization is one of the most common one. For example, placing the names of book's chapters as the concepts of the first level is a purely formal generalization. Moreover, some students did it explicitly, using the word "chapter" and its number in concepts. This suggests that the generalization to the concepts of the first level, either students did not do this at all or they could not work out semantic structure.

## 4 Typical Mistakes in Concept Mapping

Errors associated with the creation of c-maps are more indicative, because the students had to describe explicitly not only the concepts, but also the links (relations) between them.

The most representative group of mistakes – relations' type errors. A serious error in relations' determining is the misuse of relation type "A kind of" (AKO), which links a concept with a more general concept (category, class). "AKO" is one of the fundamental types of relations in the conceptual modelling. Moreover, the error can be connected both with a lack of understanding of this connection and its incorrect setting.

The most striking example is the students' attempts to define a generic concept for "electronic skin" within c-map design after reading a text about e-skin. In the first case, they missed the nature of the phenomenon, as shown in Fig. 5.

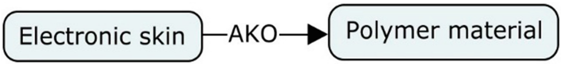


**Fig. 5.** Typical c-map's error: incorrect definition of the generic concept

Electronic skin - this is really a polymer material, but it is not informative, as if it was written, "[Glass] – AKO → [glass product]".

Students also created a relation "[e-skin] – AKO → [Skin]", which is formally true, but does not reflect the semantics. Another common error – the definition of a category using a word, which cannot be used for this purpose, as it is shown in Fig. 6.

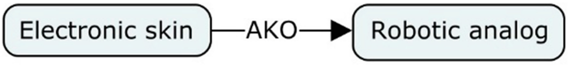


**Fig. 6.** Typical c-map's error: invalid concept as a category

The used concept "Robotic analog" is not one of independent concepts. It would be more correct to use "An analogue of the skin", but the best option – "[electronic skin] – AKO → [Robotic device/tool]".

Next, a popular error of this group was trying to use the relation "consists of" instead of "AKO". For example, a common mistake is shown in Fig. 7.

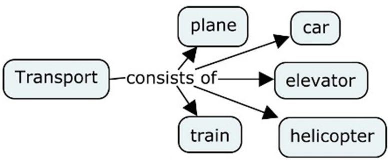


**Fig. 7.** Typical c-map's error: the replacement of "AKO" relation by "consists of"

In this case all words of the mentioned above represent means of transport, but not part of transport, so the AKO-relation had to be used.

Another significant error is misusing of the AKO-relation by replacing it with attributive relations "has property"/"has value". Thus, in Fig. 8, air transport, land transport, water and space one, are not presented as, for instance, "[Road transport] – AKO → [Transport]", but through the attributive relation "[Transport] – has property → [Environment]".

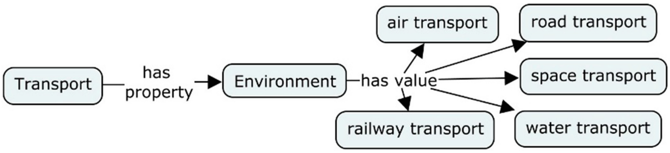


**Fig. 8.** Typical c-map's error: replacement of generic relation by attributive one

Similarly, students often used attributive relation "has property → type", for example, "[Vacation] – has property → [type] – has value → [school holidays]" instead of "[School holidays] – AKO → [Vacation]". They also often use other properties, "Wall – has property → assignment – has value → retaining wall".

In addition, a common error was met in using a relation "has value" without using "has a property" before. For example, "[Transport] – serves → [Use scope] – has value → [Personal use]". The situation "[Functioning] – has value → [5 volts]" also appeared in students works.

The second group of mistakes is semantic errors. They have different basis by mainly are related to the attempt in interpretation of text literally instead of presenting the meaning of the text or the inner sense of sentences. In this regard, when students see the word "suddenly" in the phrase "the magician will suddenly arrive", they designed relations "[will arrival] – has property → [suddenly]" or "[arrival] – has property → [unexpectedness level] – has a value → [suddenly]".

The following error, shown in Fig. 9, reflects the lack of understanding of relationship between concepts.

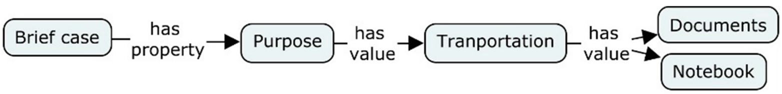


**Fig. 9.** Typical c-map's error: the use of incorrect subject-object relation

In the Fig. 9 the relation "has value" is used instead of a necessary relation "has the object of action". This error is rather often met in students' works, which also shows the difficulties of the subject-object relation understanding and visual representation.

## 5 Error Analysis

Main students' errors detected within conceptual modeling are analyzed in the Table 1. The table shows that all errors can be divided into three major groups (partially overlapping). They are:

- system-analytical errors, related to lack of structural logic thinking and abstract system thinking skills;
- syntax errors, related to lack of c-maps design's syntactic rules knowledge;
- semantic errors, caused by superficial understanding of the nature and structure of the subject domain.

**Table 1.** Students' errors interpretation

| Error type | Error | Probable cause |
|---|---|---|
| System-analytical errors | Several levels of conceptualization passing | Lack of the generalization level determining mechanism understanding and lack of hierarchical thinking understanding |
| | Incorrect definition of the generic concept | Lack of understanding of the essence of the generic concept and its definition necessity |
| | The use of unacceptable concepts as a generic concept | Inability to identify the next level of generalization |
| Syntax errors | Using the "consists of" relation instead of the "AKO" relation | Misunderstanding of the difference between the division into parts and the division into classes |
| | Using attributive relations instead of the "AKO" relation | Total misunderstanding of the generic relation's role in the conceptual modelling |
| Semantic errors | Using too specific terms on the first level of conceptualization, sometimes not quite literate; formal generalization | Lack of knowledge and depth of subject domain understanding and categorization and generalization mechanisms' misunderstanding in the conceptual structures |
| | Incorrect insertion of some specific words (for example, "where, when, etc.") into c-maps | Lack of knowledge and skills on the morphological and syntactic analysis |
| | Using of incorrect subject-object connection | The inability to accurately determine the nature of the subject-object relation, ignorance of its species |

The table shows that almost all errors are associated with difficulties in generalizations logical operation (categorization), or in the analysis procedures.

The authors may propose several methodological teaching recommendations, based on the described analysis. They all can be attributed to not only the curricula of courses «Knowledge Engineering» and «Intelligent Systems Development».

The main recommendations are:

- Courses on "System Thinking" and "Fundamentals of Cognitive Psychology" may be appropriate and useful for the students of IT-specialisations.
- It is also advisable to conduct training in using visual diagrams for knowledge modeling in various areas.
- Several classes need to be devoted exclusively for the generalization skills' control and development. For this purpose, exercises for finding a generic concept skill development and relationships' design skill development should be used.
- Visual structuring skills will be very helpful in students' research activity and academic writing.

## 6 Conclusion

Nowadays several projects are being developed, which are related to the IT-industry professional standards formation. These standards help to elaborate requirements to different areas IT-field; they describe positions and professional skills and competences according to the qualification levels [19]. Although there are many standards in the field of information technology, the specialization of analyst or knowledge engineer is the most close to the professional standard of "systems analyst". However, "System Analyst" focuses on the synthesis of software systems, while in the field of intelligent systems development the stress is put on the deep understanding and structuring of the domain knowledge that requires rather different scope of cognitive capacities and professional skills.

At the same time, structuring and visualization are becoming a powerful trend in all the branches of the information and knowledge sciences. Visual specification in the form of mind maps and c-maps can be widely used in the new forms of learning – such as e-learning, blended learning and lifelong learning. Both students and teachers can use such maps as a tool to assess the changes that have occurred in their understanding. Kozma [20], one of the developers of c-maps organization program – Learning Tool, considers these means as mind tool, which can strengthen and expand human knowledge.

Utility of the concept maps can be demonstrated by their ability to display the form of higher-order thinking. They are used for statements' formal proving the reasoning [21–23], and they are now widely used for the chemistry, biology and other disciplines studying. It was also shown that c-maps are useful in software engineering [10] and within research processes description [24, 25]. Another application of conceptual modeling is developing of graphical knowledge bases (or libraries) containing visual atlases of teaching materials for e-learning systems. For example, the ECOLE system project uses ontologies, which are also the result of conceptual modeling [26].

Knowledge engineering exercises described in this paper and students cognitive skills developed during these exercises can significantly enrich the set of competencies of future IT-specialists in the field of information processing in the age of big data and information overload. Visual structuring and modelling is in general a powerful mind tool both in teaching and learning in all the spheres of human knowledge.

## References

1. Gavrilova, T.: Knowledge engineering for non-engineers. Paper Presented at the Proceedings of IFIP 6th International Conference on Intelligent Information Processing IIP, pp. 225–234. Springer, Manchester (2010)
2. Buzan, T., Buzan, B., Harrison, J.: The Mind Map Book: Unlock Your Creativity, Boost Your Memory, Change Your Life. Pearson BBC Active, New York (2010)
3. Novak, J.D., Cañas, A.J.: The theory underlying concept maps and how to construct and use them (2008)
4. Minsky, M.: Frame-system theory. In: Johnson-Laird, P.N., Wason, P.C. (eds.) Thinking: Readings in Cognitive Science, pp. 355–376. Cambridge University Press, Cambridge (1977)
5. Novak, J.D.: Concept mapping: a useful tool for science education. J. Res. Sci. Teach. **27**(10), 937–949 (1990)
6. Kudryavtsev, D., Gavrilova, T.: From anarchy to system: a novel classification of visual knowledge codification techniques. Knowl. Process Manag. **24**(1), 3–13 (2017)
7. Gavrilova, T., Puuronen, S.: Ontological engineering for student research. Paper Presented at the Proceedings of the Second Conference on Cognitive Science, St. Petersburg, vol. 2, pp. 554–556 (2006)
8. Gavrilova, T., Leshcheva, I., Strakhovich, E.: Gestalt principles of creating learning business ontologies for knowledge codification. Knowl. Manag. Res. Pract. **13**, 218–228 (2015)
9. Koznov, D.V., Romanovsky, K.Y.: DocLine: a method for software product lines documentation development. Prog. Comput. Softw. **34**(4), 216–224 (2008)
10. Koznov, D., Larchik, E., Pliskin, M., Artamonov, N.: Mind maps merging in collaborative work. Prog. Comput. Softw. **37**(6), 315–321 (2011)
11. Buzan, T., Griffiths, C., Harrison, J.: Mind Maps for Business Revolutionise your business thinking and practice (2014)
12. Sheikhtaheri, A., Sadoughi, F., Dehaghi, Z.H.: Developing and using expert systems and neural networks in medicine: a review on benefits and challenges. J. Med. Syst. **38**(9), 110 (2014)
13. Novak, J.D.: Concept maps and Vee diagrams: Two metacognitive tools for science and mathematics education. Instr. Sci. **19**, 29–52 (1990)
14. Ausubel, D.P.: Educational Psychology: A Cognitive View. Holt, Rinehart and Winston, New York (1968)
15. Kinchin, I.M., Hay, D.B., Adams, A.: How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. Educ. Res. **42**(1), 43–57 (2000)
16. Dyachenko, O., Zagorulko, Y.: A collaborative development of ontology-based knowledge bases. Paper Presented at the International Conference on Knowledge Engineering and the Semantic Web, pp. 219–228. Springer, September 2014
17. Cañas, A.J., Hill, G., Lott, J.: Support for constructing knowledge models in CmapTools. Technical report IHMC. Institute for Human and Machine Cognition, Pensacola (2003)

18. Gavrilova, T., Kudryavtsev, D., Leshcheva, I., Pavlov, Y.: On a method of visual models classification. Bus.-Inform. J. **26**(4), 32–44 (2013). (in Russian)
19. Miller, T.K.: CAS, the book of professional standards for higher education 2003. Council for the Advancement of Standards in Higher Education (2003)
20. Kozma, R.B.: Constructing knowledge with learning tool. In: Kommers, P.A.M., Jonassen, D.H., Mayes, J.T., Ferreira, A. (eds.) Cognitive Tools for Learning. NATO ASI Series (Series F: Computer and Systems Sciences), vol. 81. Springer, Heidelberg (1992)
21. Mikulescky, L.: Development of Interactive Computer Programs to Help Students Transfer Basic Skills to College Level Science and Behavioral Sciences Courses. Indiana University, Bloominglon (1988)
22. Schlenker, D., Abegg, G.: Scoring student-generated concept maps in introductory college Chemistry. Paper Presented at the Annual Meeting of National Association for Research in Science Teaching, Lake Geneva (1991)
23. Eppler, M.J.: A comparison between concept maps, mind maps, conceptual diagrams, and visual metaphors as complementary tools for knowledge construction and sharing. Inf. Vis. **5**(3), 202–210 (2006)
24. Goldsmith, T.E., Johnson, P.J., Acton, W.H.: Assessing structural knowledge. J. Educ. Psychol. **83**, 88–96 (1991)
25. Novak, J.D.: Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Routledge, London (2010)
26. Vasiliev, V., Kozlov, F., Mouromtsev, D., Stafeev, S., Parkhimovich, O.: ECOLE: an ontology-based open online course platform. In: Open Data for Education, pp. 41–66. Springer (2016)

# On Mind Maps Evaluation: A Case of an Automatic Grader Development

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**Abstract.** Nowadays, mind mapping is a rather popular educational technique. Moreover, mind maps became a part of modern educational trends like blended learning and computer-supported collaborative learning. Lots of mind mapping software tools are adopted to teaching and learning routines such as educational content delivery or assessment. This paper focuses on the additional automatic evaluation of digital educational mind maps gained from the existing procedures of assessments. The review of automatic graders which support the evaluation process demonstrated that some systematical work is done in automation grading by comparing students' mind maps with a template. But lots of questions about automatic mind maps' scoring by retrieving the data from a scored mind map are still open. This paper introduces the automatic grader for educational mind maps (AGEMM) which acts like a teacher's assistant and calculates several quantitative metrics. The AGEMM is implemented as a web-service and interacted with digital mind maps prepared in the Coggle web-service through its API. The AGEMM is adopted to the Scientific Research Seminar of "Marketing" bachelor program in National Research University Higher School of Economics (Perm). Results demonstrate that scores from the AGEMM may be transformed to scales or criterial levels which are used to evaluation. Moreover, the AGEMM application revealed several problems and shew lines of development which we discuss in the paper.

**Keywords:** Mind map · Education · Collaboration · Evaluation Grading · Software

## 1 Introduction

These days popularity of mind mapping as an educational approach is growing [1]. Firstly, this caused by that different educational tasks (e.g. lessons delivery, self-evaluation, students assessment) may be successfully resolved by using mind maps (MMs) [2–4]. Secondly, MMs proved their reliability and efficiency as in STEM education as in social disciplines and humanities [5, 6]. And, consequently, MMs are effectively adopted by educators from different fields [7–10]. The context of this paper


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lays in the field of digital mind mapping in computer supported formative assessment and focuses on the automatic scoring and evaluation of MMs.

Application of digital MMs for teaching and learning creates some challenges for MMs adaptation. First challenge is selection of software suitable to educational needs. Second one is grading of students' MMs. Assuredly, teaching with MMs requires from teacher to gather students MMs and to evaluate them. Evaluation in this case is the process with rising laboriousness. High difficulty of evaluation makes educational mind mapping a poor scalable technique. But the automatization of this process can increase scalability. So, the questions of automatic mind maps evaluation are on the front of burner. This paper aims to introduce the *Automatic grader for educational mind maps* (AGEMM) which supports the routines of evaluation of digital MMs gained from the midterm assessment process.

What do we know about the current state of automatic scoring and evaluation of MMs? Literature review demonstrates two significant gaps. First is that the most of mind mapping software products are universal and do not design as educational tools. Consequently, they do not support any automatic assessment of MMs. The second gap is dedicated among the existing automatic graders for MMs. These graders support knowledge assessment in disciplines where technical vocabulary is explicitly defined [11]. However, memorizing technical vocabulary is not the most important learning outcome for many courses and memorizing is not the most important function of MMs as a learning technique. Therefore, automatic grading for learning outcomes beyond memorizing is still poorly automatized.

## 2 Mind Map Evaluation in Education

### 2.1 What Do We Know About the Grading of Educational Mind Maps?

This section gives the overall picture of educational MMs grading methodology. We aim several purposes: to understand significant quantitative and qualitative features of educational MMs and the way of their measurement; to overview the existing AGEMMs and their compatibility with popular mind mapping tools.

The question of educational MMs evaluation is quite complicated and requires exact and consistent grading rules. Indeed, grading rules are strongly depended on an assessment type, learning objectives and outcomes. Thus, brothers Buzan in [12] suggested the following criteria: an answer detailing, authors new ideas, quality of a MM (e.g., color, symbols, arrows). Evrekli and the colleagues in [13] introduce grading rules that include the number of levels in a MM (each level costs more than a previous one), correctness of relationships between concepts of one brunch and associations between concepts of different brunches, the exploitation of pictures, symbols and shapes. Integration these results with students' experience and investigations in this field have already led the authors to several obligatory grading criteria [14]. Note that some estimations for quantitative characteristics of digital MMs discussed by Beel and Langer in details [15].

It is well known that several research groups have studied quantitative properties of MMs and introduced different metrics [6, 11, 16]. The main weakness of these works is the dependencies between the metrics and a reference (template) MM. On the contrary, we suggest the approach which on the first levels takes into consideration independent (from the template MM) metrics of the evaluated MM and comes from the recommendations to grading rules.

Franklin and the colleagues in [17] developed the methodology for automatic analyzing technical vocabulary which is used by students in their MMs. Our approach differs from the mentioned one in several key features. Firstly, we use MMs as independent work, unlike the cited authors who used MMs as a class assessment technique. Secondly, our approach does not rely on a criterion MM as a reference pattern. Thirdly, our MMs focused on task, but not on topic. The source of these differences are educational goals of Scientific Research Seminar, which are not only to provide necessary vocabulary, but also to stimulate deep involvement into research project, deep investigation for literature review and usage relevant interdisciplinary information. So, our goal is to develop the tool which assesses not only student's technical vocabulary and general understanding, but also involvement, breadth and depth of task fulfilment.

Although opportunities for automatic grading of MMs are limited, digital mind mapping is quite popular among educators it causes several problems. At first, gathering of students MMs needs to settle an extra process which leads to the expansion of technological stack in most of cases. At second, if the number of students is large and a teacher evaluates all MMs himself/herself, or calibrated peer assessment is implemented, the laboriousness of the evaluation process grows rapidly. Furthermore, several valuable researches have been done in this field [17, 18], but most of them concern on automatic assessment students' technical vocabulary based on a predetermined criterion MM.

This paper introduces the approach to automatic grading of MMs on four levels and focuses on checking some quantitative properties of a MM (nodes count, associations count, embedded images count, branching levels, etc.) which is the first level of AGEMM.

### 2.2 Mind Map Formalization

The process of software design undoubtedly strongly requires definitions and clear understanding of an automatizing object. From a technological point of view, a MM is represented by a **weighted rooted tree of concepts** which has extra features:

- an additional layer of associations between concepts;
- node's weights: node's content and a set of concept's visual properties, such as size, shape, color, images, rich text attributes, etc.;
- edge's weights: a set of link's visual properties, such as shape and color;
- an explicit circular layout of MM elements with root concept in the center.

We will use the term MM to address a thinking method and its main visual artifact.

### 2.3 Interactive Assessment Process of an Educational Mind Map

Let us show a place of automatic grader in educational process which deals with MMs. The BPMN-diagram at Fig. 1 demonstrates that a teacher and a student interact during

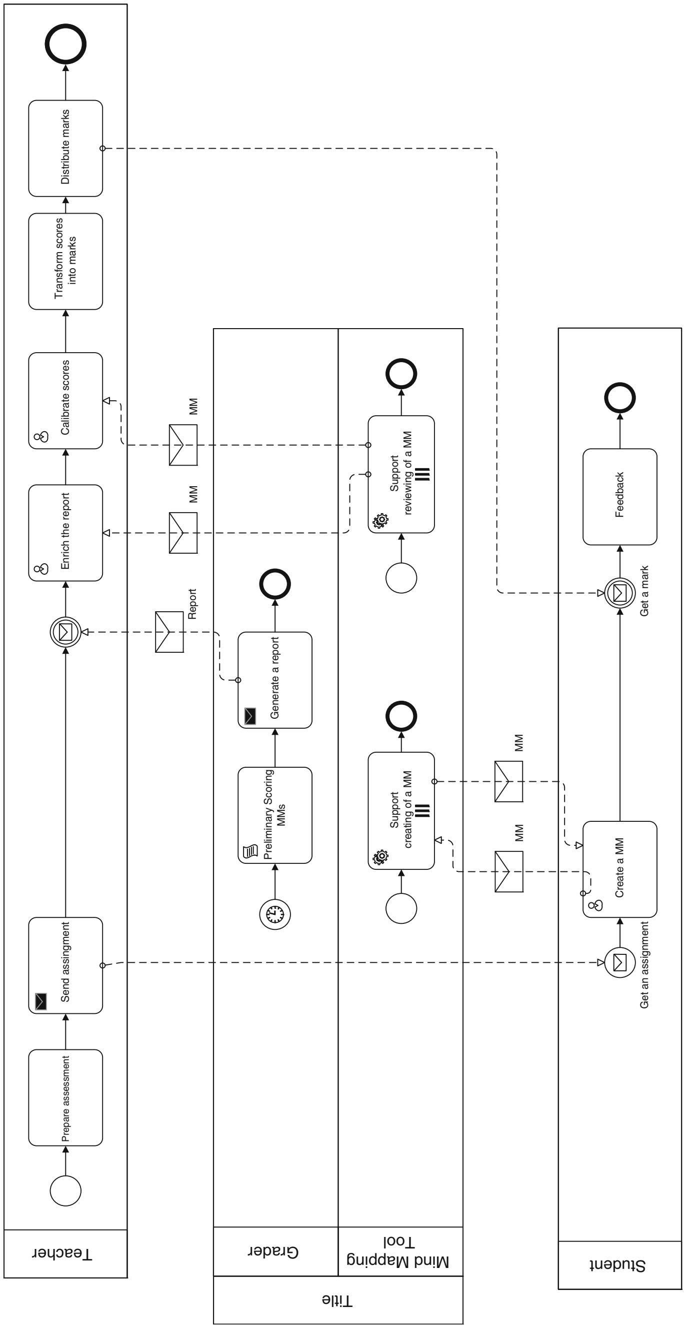


**Fig. 1.** BPMN diagram of MM's assessment process

the assessment through the mind mapping tool and the AGEMM. This diagram also shows that AGEMM acts as an assistant tool to support routines and to build preliminary grades. The mind mapping tool and the AGEMM should be understood as a single system which in practice may be implemented as a set of integrated services.

### 2.4 Grading Metrics

As it follows from Sect. 2.1 computer-aided grading metrics reflect quantitative characteristics of MMs' quality. Surely, in educational case this also means interrelation between these metrics and the evaluation criteria of MMs. In this section, we suggest an approach to grading, introduce a list of metrics which are implemented in developed AGEMM and describe their connections with the evaluation criteria that we previously developed, adopted by the authors [14].

We distinguish following four levels of MM analysis that can be aided by computer. Criteria for distinguishing between those levels are the main method of a MM's analysis, the difficulty of formalization, the subjectivity of evaluation, and the computational complexity.

1. Calculating basic quantitative properties of MM graph structure and nodes' content.
2. Simple text analysis based on predefined set of keywords.
3. MM graph similarity analysis.
4. Ontology-driven analysis of MM semantic.

The second level requires using of predefined keywords ($WS$ – set of keywords, $|WS| = WSCount$) and parameters of intermediate text processing (stemmer, stop word list, etc.) as an additional input. The main idea of this level is simple and has been already prototyped but require the additional adjustment of parameters for practical application. The authors work on basic instrumentation for next two levels and do not consider them in this paper.

Table 1 contains the list of basic quantitative properties of the first level.

**Table 1.** Basic quantitative properties of the first level of MM grading

| Title | Id | Type, Measure | Sense |
|---|---|---|---|
| Associations Count | `Associations` | Integer, ≥ 0, Associations | Count of associations in MM |
| Longest Path Length | `Max_height` | Integer, ≥ 0, Edges in path | Number of edges in longest path from root to leaf in MM |
| Nodes Count | `Count_nodes` | Integer, ≥ 0, Nodes | Count of Nodes in MM |
| Root Branches Count (Root Degree) | `Count_first_layer_branches` | Integer, ≥ 0, Nodes | Number of basic concepts |
| Images Count | `Images` | Integer, ≥ 0, Images | Number of images in MM |
| Average Node Text Length | `Avg_node_text_len` | Float, ≥ 0, Words | Average length of node's text (in words) |

Presented quantitative properties reflect elaboration of a MM. The Root Branches define the subject area of the MM and its structure. Less than tree branches witness about poor knowledge on the area, whereas more than eight marks lack of structure in a student's knowledge. This property also demonstrates the student's critical thinking and originality while the MM was creating. Nodes show how many concepts student employed for the MM. The length of path displays how many layers the MM has, that is how deep elaboration of each basic logical idea is. Average node text length meets Buzan's requirement of limitations for usage of words. Looking for the best pairs of words for each node the student rethinks the content of the MM.

## 3 AGEMM Technical Description

This section gives a brief technical description of the introducing AGEMM. Here we prove the selection of a base platform and touch the questions of authentication and interoperability.

The comparison of popular mind mapping tools (see summary in Table 1) demonstrates that the *Coggle* seems to be the most suitable free collaborative software to be applied to the educational tasks. Indeed, at the one hand most of mind mapping tools are proprietary and carry a price. This limits their application to educational courses without university-wide subscription. At the other hand, lots of mind mapping tools do not support collaborative work and do not have any API to operate with MMs by external services.

MMs which are created in the *Coggle* can be automatically evaluated by an external grader through *Coggle API*. This service has useful user interface, high collaborative abilities and all necessary functions for creating MMs. Moreover, the *Coggle* provides the RESTful API to work with MMs and allows to authorize an application using authentication flow of OAuth 2.0 framework. All the methods of the *Coggle API* can be found in the guideline [19]. The authors strongly believe that the *Coggle* provides the most convenient free instruments for collaborative creation and following grading of MMs.

For now, RESTful interfaces are known as the simplest way to resource-oriented web-service interaction with quite mature methodology [20]. Commonly, a developer expects that a REST-interface gives abilities similar to that provided by a user interface. Unfortunately, for now the *Coggle* does not fulfill these expectations. For example, today the *Coggle* REST-interface does not provide some important features useful for MM grading:

– Ability to get an arbitrary node by its unique identifier.
– Ability to get associations without parsing the text of nodes.

Nevertheless, listed limitations of the API do not seriously prevent its utilization to AGEMM development needs due to initial loading MM into AGEMM data model (Table 2).

**Table 2.** Comparison of popular MM creation tools

| Title | Link | Free | Web-UI | Collaboration | API | Export formats | Import formats |
|---|---|---|---|---|---|---|---|
| GoConqr | www.goconqr.com | − | + | −/+ | − | png | − |
| MindMup2 | www.mindmup.com | +/− | + | + | − | mm, mup, pdf, png, txt | mm, mup |
| WiseMapping | www.wisemapping.com | + | + | +/− | − | mm, mmap, wxml, pdf, jpg, png, svg, txt, xls, odt | mm, wxml |
| Freemind | freemind.sourceforge.net/wiki/index.php/Main_Page | + | − | − | − | − | mm |
| MindMeister | www.mindmeister.com | − | + | + | REST | pdf, rtf, docx, pptx, png, jpg, mmap, mind, xmind, txt | mm, mmap, mind, xmind, txt |
| XMind | www.xmind.net | − | + | − | − | docx, pptx, xlsx, pdf, rtf, html, txt, png, jpg,gif, etc. | mm |
| ConceptDraw MINDMAP 9 | www.conceptdraw.com/products/mind-map-software | − | −/+ | − | − | doc, pdf, html, xml, jpg, png, bmp, txt, rtf, mmap | mm, mmap, xmind, doc, pdf, txt, opml |
| Mindjet MindManager | www.mindjet.com/mindmanager/ | −/+ | −/+ (viewer) | − | − | Html | html |
| Coggle | coggle.it | +/− | + | + | REST | mm, pdf, png, txt | Mm, txt |

AGEMM is implemented as a RESTful web-service with a simple front-end for dealing with Excel files with a list of students and links to corresponding MMs (Fig. 2). Excel file (workbook) requires containing a table with shared public links to *Coggle* MMs in the second column of the first worksheet (Fig. 3). Results of the grading can be downloaded as a new Excel file where grader has appended columns with calculated metrics (Fig. 4).

The AGEMM web-service is written on Python and build on top of Django REST framework [12]. The source code of the web-service is open and is hosted on Bitbucket (http://bitbucket.org/aparinov/pycoggleit). At the current state, the code contains methods for authorization, loading URIs of public diagrams from a file, calculating diagram metrics, and appending calculated metrics to a file.

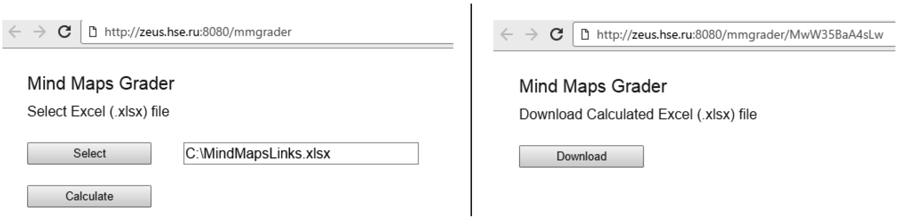


**Fig. 2.** User interface of AGEMM web-service

| Name | Coggle MindMap Link |
|---|---|
| A. Jones | https://coggle.it/diagram/WHIfmNEj |
| J. Spenser | https://coggle.it/diagram/Wdpnz/6ee6d2 |

**Fig. 3.** Example of Excel file with list of MM's links

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | diagram | associations | max_height | count_node: | count_first_l | images |
| 2 | https://coggle.it/diagram/WHIfmNEj | 2 | 2 | 4 | 2 | 0 |
| 3 | https://coggle.it/diagram/WIpGDBml | {"error": "Error 403: Permission denied"} | | | | |
| 4 | https://coggle.it/diagram/WI9Q_z3N | 2 | 4 | 33 | 7 | 2 |
| 5 | https://coggle.it/diagram/WIo97WgG | 0 | 3 | 29 | 8 | 6 |

**Fig. 4.** Example of Excel file with list of MM's links and calculated metrics

# 4 AGEMM Adoption

The AGEMM was firstly adopted into Scientific Research Seminar for the 3-th, 4-th year students of the "Management" bachelor program of National Research University Higher School of Economics (Perm) in 2016/2017 academic year. Note, that mind mapping approach is not new for authors and was previously successfully implemented in the "Marketing" master program repeatedly.

## 4.1 Data Collection and Description

The data collected from the midterm assessments which were based on MMs and delivered by means of *Coggle*. General population was consisted of 4-year students of the "Management" bachelor program. The volume of the research sample was 81 observations. Each observation contains 13 measurements from AGEMM and teacher. The first five values are scores gained from AGEMM (see Section, Table 1 for metrics details): associations, max_height, count_nodes, count_first_layer_branches, images. Another six are scores for evaluation criteria. And two more values are the exam score and the total score. General quantitative information about observations is given in Tables 3, 4 and 5.

**Table 3.** Scores from AGEMM

| | associations | max_height | count_nodes | count_first_layer_branches | images |
|---|---|---|---|---|---|
| MIN | 0 | 2 | 28 | 2 | 0 |
| MAX | 30 | 9 | 178 | 11 | 51 |
| Median | 6 | 5 | 68 | 5 | 10 |
| Mean | 6.09 | 4.99 | 71.47 | 5.17 | 12.88 |

**Table 4.** Statistics of scores by criteria and final results

| | Basic logical ideas | Logic | Interdisciplinarity | Number of links | Number of levels in a MM | Performance of a MM | Exam | Result |
|---|---|---|---|---|---|---|---|---|
| MIN | 5 | 5 | 0 | 1 | 3 | 1 | 3 | 4 |
| MAX | 10 | 10 | 10 | 8 | 8 | 9 | 10 | 9 |
| Median | 7 | 7 | 7 | 8 | 8 | 7 | 7 | 7 |
| Mean | 7.15 | 7.1 | 6.38 | 6.89 | 7.94 | 6.85 | 6.7 | 6.96 |

**Table 5.** Initial grading criteria from course author

| Criteria | Explanation |
|---|---|
| Number of levels in a MM | Not less than 3 levels |
| Interdisciplinarity | Reasonable using concepts and theories from the other disciplines |
| Basic logical ideas | Correctness, volume, student's approach |
| Logic | Proportion of concepts' volumes, correctness of sequences, no duplications |
| Number of associations | Not less than 1, no more than 5 |
| Performance of a MM | A student uses in MM adequate images, different colors, and fonts. If these visualization is missed a student yearns 0 points |

A teacher used a scale with 10 points from 1 to 10, where 1–3 are "unsatisfactory", 4–5 are "satisfactory", 6–7 are "good", and 8–10 "excellent".

## 5 Results and Discussion

The AGEMM proposed in this paper was successfully implemented as a RESTful web-service with a simple front-end for dealing with Excel files with a list of students and corresponding links to MMs.

The adoption of the AGEMM reveals several problems. The first one is a procedural and appears if students give to a teacher private links to MMs or forget to share MMs. This was caused by that many students did not to read *Coggle* tutorial. In other cases, the AGEMM demonstrated stability and correctness.

As far as the main goal of the suggested in the paper AGEMM is to be an assistant tool and reduce teacher's effort during the evaluation of educational MMs, the metrics should reflect teacher's scores. The adoption shows that values of the metrics are quite close to teacher's scores and only some of them were increased or decreased by a teacher. Figure 5 demonstrates this fact, for example, student #17 has 8 basic logical ideas, but his teacher's score is not excellent. On the contrary students #18 and #22 have only 2 and 4 basic logical ideas correspondingly, but they cost 10 from the teacher's point of view. There are no doubts that this explains by that a teacher is an expert in the field and evaluates not only the quantity of the ideas at the first layer, but their content and agreement with a subject. Thus, the AGEMM can be improved by adding some semantic analysis functionality. This opens the perspective of using ontology-driven text mining to MMs' evaluation.

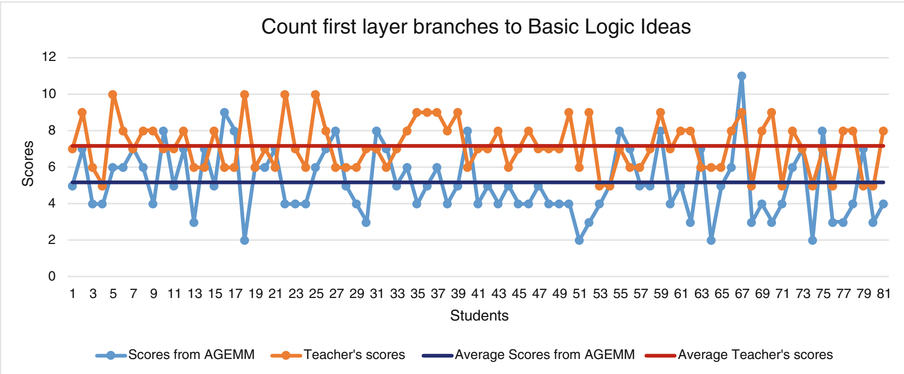


**Fig. 5.** Conformity of scores from AGEMM and teacher's scores

The results of adoption let us clearly recognize some plans for future work:

- To analyze results of several additional sessions and make more precise rules for keywords analysis (the second level).
- To add a structural similarity based assessment (the third level). The service will be able to calculate several measures of similarity between a graded MM and preliminary given reference MMs.
- To implement OAuth 2.0 authentication and users database management.

## 6 Conclusion

The work introduced the Automatic Grader for Educational Mind Maps (AGEMM) which aims to support a teacher while evaluating digital MMs used as a tool of midterm assessment. The AGEMM is an assistant for teacher and consists of two parts of grading: automatic for formal counted part and manual for content part. For now, AGEMM fully implements the first level and partially the second level of four introduced in our approach:

1. Calculating basic quantitative properties of a MM graph structure and nodes' content.
2. Simple text analysis by keywords.
3. A MM graph similarity analysis.
4. Ontology-driven analysis of a MM semantic.

The pilot of the presented AGEMM demonstrated that two more metrics are required for assessment task oriented MMs without a criterion MM. The first metric is the average number of words per a node. It demonstrates a student's efforts in rethinking and transformation of information he or she uses for MM creation. The second metric is the proportion between the number of images and number of nodes. This metric shows how many images are used for MM construction. Both metrics meet important requirements for MMs introduces by Buzan [20] and display the level of involvement and critical thinking.

Another important requirement of MMs are horizontal ties aimed to push critical thinking and unconventional ideas. This part may be the toughest one for students and teachers. Students tend to create as many connections as possible overwhelming MMs and aggravating assessment. To prevent abundance of odd connections program needs reduction of grades after the fifth association and some tool for marking of good association during manual assessment.

Nevertheless, the AGEMM has been successfully developed and adopted to educational practice, this research has a remarkable limitation. The most significant one is the examination of only first pilot of AGEMM adoption. Thus, any essential conclusions about correlations between the scores from the AGEMM and total scores cannot be done based on described samples. However, this limitation does not decrease the practical value of the developed AGEMM. The authors suppose that the implementation of higher levels of the AGEMM enlarges number of users and allows to enhance the evaluation of MMs.

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## References

1. Mind map for teaching. Edraw. Visualization Solutions. https://www.edrawsoft.com/mindmap-usage-for-teaching.php. Accessed 05 May 2017
2. Willis, C., Miertschin, S.: Mind maps as active learning tools. JSCS **21**(4), 266–272 (2006)
3. Budd, J.: Mind maps as classroom exercises. J. Econ. Educ. **35**(1), 35–46 (2004)
4. Wittkower, D.: Mind-mapping inside and outside of the classroom. In: Learning Through Digital Media: Experiments in Technology and Pedagogy, pp. 221–229. Institute for Distributed Creativity (2011)

5. Dhindsa, H., Makarimi-Kasim, Anderson, O.: Constructivist-visual mind map teaching approach and the quality of students' cognitive structures. J. Sci. Educ. Technol. **20**, 186–200 (2011)
6. Evrekli, E., Inel, D., Balim, A.: Development of a scoring system to assess mind maps. Procedia Soc. Behav. Sci. **2**, 2330–2334 (2010)
7. Lai, C., Lee, M.: The effects of mind-mapping technique in engineering mathematics. In: IEEE 8th International Conference on Engineering Education (ICEED), pp. 261–264 (2016)
8. He, F., Miao, X., Wu, B., Yao, S.: Using mind map as learning tool in "Data Structure" teaching. In: IEEE International Conference on Computer and Information Technology, pp. 761–764 (2014)
9. Zipp, G., Maher, C.: Prevalence of mind mapping as a teaching and learning strategy in physical therapy curricula. J. Sch. Teach. Learn. **13**(5), 21–32 (2013)
10. Evrekli, E., Inel, D., Balim, G.: Mind mapping applications in special teaching methods courses for science teacher candidates and teacher candidates' opinions concerning the application. Procedia Soc. Behav. Sci. **1**, 2274–2279 (2009)
11. Franklin, A., Li., T., Jamieson, P., Semlak, J., Vaderbush, W.: Evaluating metrics for automatic mind map assessment in various classes. In: Frontiers in Education Conference (FIE), pp. 1–8 (2015)
12. Evrekli, E., Inel, D., Balim, G.: Mind mapping applications in special teaching methods courses for science teacher candidates and teacher candidates' opinions concerning the application. Soc. Behav. Sci. **1**, 2274–2279 (2009)
13. Beel, J., Langer, S.: An exploratory analysis of mind maps. In: DogEng 2011, pp. 81–84. ACM (2011)
14. Jamieson, P., Eaton, J.: Towards a better graphlet-based mind map metric for automating student. In: 122nd ASEE Annual Conference and Exposition, Seattle (2015)
15. Franklin, A., Sunderhaus, R., Bell, C., Jamieson, P.: Improved method for creating criterion maps for automatic mind map analysis. In: Frontiers in Education Conference, pp. 1–6 (2016)
16. Jemieson, P.: Using modern graph analysis techniques on mind maps to help quantify learning. In: Frontiers in Education Conference (FIE), pp. 1–6 (2016)
17. Coggle. Coggle API Documentation. https://embed.coggle.it/diagram/532f2f5007eb88f857000976/06b3a62e14eb54cf7e99086f3cf7dd0398af0ecca4476a8778cad4a67eba53bb. Accessed 15 Feb 2017
18. Apigee Corp. Web API Design: The Missing Link. https://docs-apis.apigee.io/files/Web-design-the-missing-link-ebook-2016-11.pdf. Accessed 25 Apr 2017
19. Christie, T.: Home - Django REST framework. http://www.django-rest-framework.org/. Accessed 25 Apr 2017
20. Buzan, T., Buzan, B.: The Mind Map Book: Radiant Thinking - Major Evolution in Human Thought, 3rd edn. BBC Active, London (2003)

# Training in Research on Cognitive Control Systems

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**Abstract.** In the coming decades, a new round of scientific and technological revolution is expected in the world. A person will be surrounded by artificial intellectual systems based on knowledge — cognitive systems. The existing education system is focused on giving knowledge about previous generations of intelligent systems — IoT, CPS, and should be transformed. The required amount of knowledge can no longer be transferred to a trained specialist within the framework of existing teaching technologies. Therefore, skills of using, extracting and transforming knowledge become the basis of promising technologies of continuous self-education. To determine a direction of studying cognitive control systems, a model of a structure of such system is proposed, based on control levels. Each level of this model corresponds to procedures for transforming forms of knowledge that need to be studied by a future engineer. To favour the development of students' self-education skills, it is suggested to sharply increase the amount of research assignments in the practice of teaching almost all technical curricula studied at universities. Examples of such tasks in physics, electrical engineering and other disciplines are given. Some of these examples are about "black box" objects; another need the application of a non-standard approach to ADC. Besides, a way of using ternary logic and logical inference to assess the quality of knowledge obtained by the cognitive control system is considered.

**Keywords:** Cognitive control systems · Models of cognitive control systems
Research assignments · Engineering education

## 1 Introduction

There are no doubts that the pace of technological innovations continue to increase rapidly in the twenty-first century, and educational system should be changed in order to give new generations of engineers the opportunity to thrive in a professional environment [2]. The ways of providing these changes are considered from different points of view.

According to [14], the main components of engineering education can be described as knowledge, skills, and attitudes that dictate the goals toward which skills and knowledge are directed. Since the volume of information is increasing far more rapidly than the ability of engineering curricula to "cover" it, the focus shifts away from the simple presentation of knowledge toward the integration of knowledge [14]. For instance, in


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Advances in Intelligent Systems and Computing 716,
https://doi.org/10.1007/978-3-319-73204-6_26

[6] was reported about teaching mathematics within electrical engineering courses; authors of [17] informed of a multidisciplinary course “Engineering Discovery” for first-year students; a model curriculum proposed in [2] merges the disciplines of mathematics, science, engineering, and computing.

The skills required for future engineers may be determine from different perspectives [14]. In this paper, predominant attention is paid to two of them. The first one is define as commitment to lifelong education [16]. The other skill was described in [5] as ability to identify the system’s emergent properties, capabilities, behaviors, and functions without looking inside the system and its parts/components/details. This skill seems to be crucial so far as the Fourth Industrial Revolution is expected [15], and a person will be surrounded by artificial intellectual systems that will continuously explore an object of control, themselves and environment. For building these so called cognitive systems, future engineers should know methods of their processing, be able to extract and use the data.

## 2 State of Art

It cannot be said that these issues are not given attention in the modern system of engineering education — research projects are present in university programs for graduated students. For example, students of Electrical Engineering Department of Zaporizhzhya National Technical University study a course “Automation and Informatization of Scientific Research” [1]. According to the framework of this curriculum, such methods of changing knowledge forms as signal processing, fuzzy logic, neural networks, cluster analysis, genetic algorithms, logical programming and others are considered.

However, a lot of study time is spent on learning principles of systems’ component operation, and confirming operability and effectiveness of a certain method. This leads to an undesirable situation when research potential of a future engineer does not accumulate, students do not develop skills to determine and choose a method for investigating an object of unknown structure.

The literature analysis allowed us to reveal some reassuring empirical results about teaching students to deal with such objects, so-called “black boxes”. For instance, in [9] the author described her experience of using black box method both in the classroom and in the education of future physics teachers. The author also noted that besides the experiments with black box foster the creativity of students many teachers don’t seem to be familiar with it.

In [7] was reported about a laboratory course of Electrical & Electronics where a black box has been provided to each student during final exams. The authors claimed that in this way a student’s best creativity is highlighted. It is also worth to mention that results of educational researches in another field — a Computer Science/Software Engineering indicate in favour of this approach. In [3] was noted that software testing principles and techniques have been identified as one of the areas that should be integrated early in the curriculum.

We would like to emphasize that time is definitely an important factor for developing students’ research skills. There is no hope that it is possible to ensure appreciable changes during one-semester course at the end of university education. Therefore, it is necessary to create a specially constructed series of task which could be integrated in different courses starting with basic curricula such as Physics and Electrical Engineering.

Another important factor that should not be forgotten is the psychological atmosphere, the style of teacher-student interaction. It is doubtful that first students' attempts to solve a problem of unfamiliar type will be successful, thus a teacher has to be able to encourage and inspire them.

This work is aimed at presenting a way of purposeful training for students to identify properties of cognitive control systems through several curricula. Certainly, the approach used for forming this skill must be linked to a structure of corresponding systems [10]. Since models of such structure are currently under formation, it was necessary to begin our study from elaboration a model of a cognitive control system.

## 3 Model of a Cognitive Control System

The proposed structural model of a cognitive control system is shown in Fig. 1. This model describes a cognitive control system in the form of a hierarchy of control levels (from the target to the direct) where subsystems of a corresponding level are located. Describing cognitive systems, it is necessary to determine a knowledge base in a form which is typical for a given level; rules for converting this knowledge into a form of the next level of the knowledge pyramid [13]; goals of management in categories of activities and management functions at a given level.

An activity of a subsystem is formed by a finite-state machine (FSM) of this level and aimed at managing knowledge converters at this level, managing downstream levels and informing a higher level about the results of their activities.

The principle of knowledge homogeneity is applicable to subsystems of each level. According to this principle, both knowledge about a control object which is stored in a knowledge base, and knowledge which is underlying control algorithms can be processed. On the level of computing systems, this principle is known as the Von Neumann principle of memory homogeneity. Application of this principle allows to build hierarchies of controls in which the control device on the $i$-th level becomes the control object on the higher $(i + 1)$ level.

An example of the described model possible application to a system which controls cooling of an oil-filled power transformer is shown in Table 1.

The proposed structural model of a cognitive control system allows to decompose it into simpler subsystems, to identify typical elements, to detail their interfaces and, ultimately, to organize appropriate learning process for students.

Research assignments for students have to include objects with unknown to them structure. A trainee should investigate them by examining signals, data, information, knowledge, understanding, and wisdom. Methods of extracting knowledge of higher forms from knowledge in lower forms must also be studied: data from signals, information from data, etc.

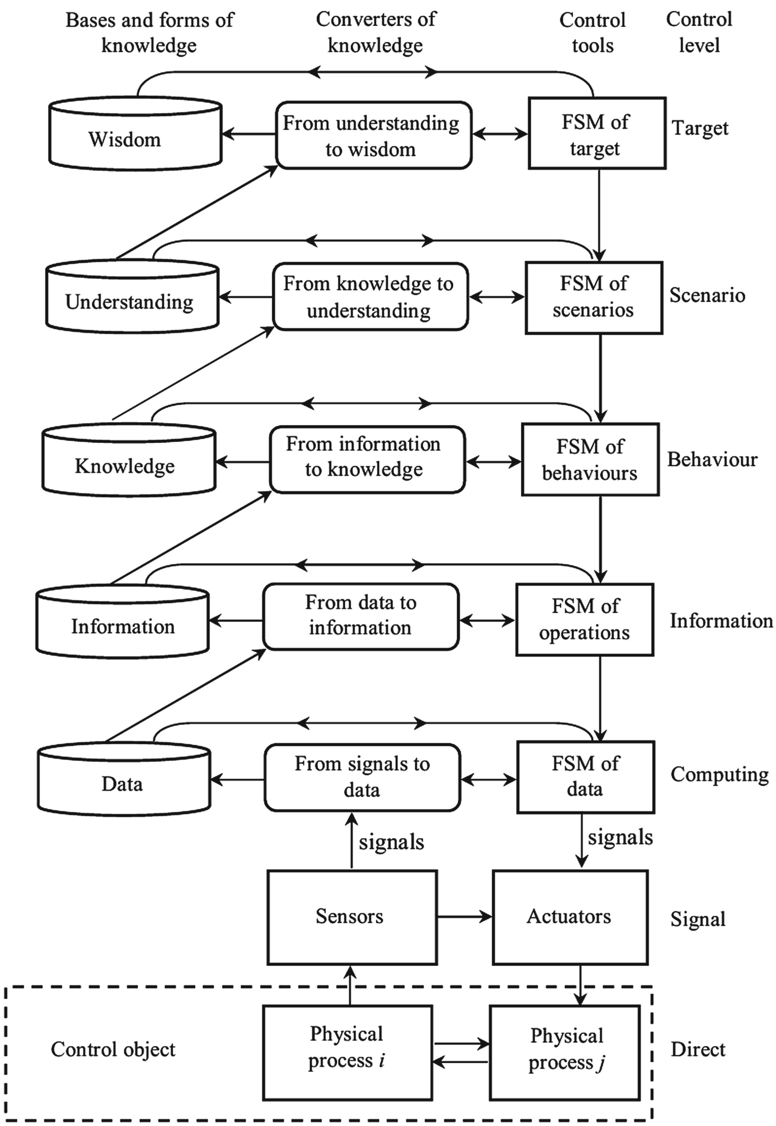


**Fig. 1.** Model of a cognitive control system

**Table 1.** Elements of a cognitive cooling control system based on the fuzzy controller [11]

| Element of the cognitive system | Value |
|---|---|
| Analog input No. 4 "Load current sensor" | Voltage 1.35 V |
| Record XXX in the database | The system time is 11145964; Value 1871 |
| Record XXX in the information base | The time is 06:45; Date May 8, 2010; Load current 221.5 A |
| Record XXX in the knowledge base | The load parameters are normal and correspond to the forecast |
| Recording XXX in the understanding base | In the near future, a sharp increase in the load current is expected; this will lead to undesirable overheating of the control object |
| Recording XXX in the wisdom base | It is necessary to reduce the consequences of the expected overheating of the control object |
| State of the FSM of target | Assign a priority objective to prevent overheating of the control object |
| State of the FSM of scenario | Scenario advanced control of cooling control object to assign a priority scenario |
| The state of the FSM of behaviour | Start the thermodynamic model of the control object. Connect the temperature forecast channel of the control object to the cooling system controller |
| State of the FSM of operation | Select the switching point and the operating mode of the cooling system of the control object |
| State of the FSM of data | On the discrete output number 7 to form a "logical 1" at the time of the system time 11146000 |
| Discrete output number 7 "Fan drive" | Voltage 24 V |

## 4 Research Tasks on the Study of a Cognitive Control Systems

In this part of the paper we present a series of assignment samples which might favour the development such important skills for future engineers as commitment to self-education, and ability to work with unknown structure systems.

**Example 1** (Physics). A three-pole "black box" with no more than three resistors inside is offered to students. They have to propose possible versions of these resistors connecting, and find their values. Electrical resistance between terminals A, B, and C of a "black box" is known. For carrying out experiments, both real ABC circuits and their software emulators with generators of random resistance values and topology of ABC circuits could be used.

An unexpected but crucial gap in our students' knowledge was found by one of the authors at the beginning of the semester when trainees could not solve this problem. It was quickly elucidated that the difficulty did not connect with knowing corresponding physics formulas. When students had to calculate the resistance between the external outputs of circuits (see Fig. 2) almost all of them correctly identified these resistances using formulas for serial and parallel connection of conductors. However, when the group was assigned to research option with a "black box", most of students could not fulfil the task, and needed a clue. After that the trainees carried out all possible experiments, compiled and solved systems of linear equations for each of the possible configurations of the scheme under study.

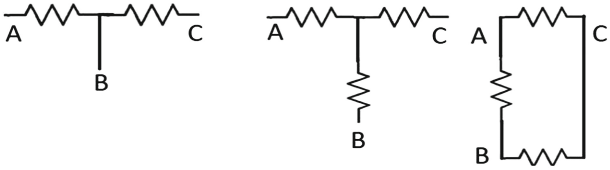


**Fig. 2.** ABC circuit options

This situation strikingly shows the need to expand the scope of research assignments, and include them in curricula learned from the first days of study at university.

**Example 2** (Electrical Engineering). Students have to determine if there are reactive elements or p-n junctions in a circle.

Such tasks could be used with the purpose of complicating the experiments from the previous example. Semiconductor diodes connected in series or in parallel to the resistors are inserted in the ABC circuit. Students have to diagnose the presence of diodes by differences in measurement results obtained in forward and reverse directions of a circuit.

This assignment could be extended by asking students to measure resistors in the ABC circuit which were connected in parallel to the p-n junctions. For fulfilling this task students have to measure resistances at voltages less than 0.3 V when the p-n junctions of the diodes have a high electrical resistance both in reverse and forward directions.

**Example 3** (Electrical Engineering). Students have to define a frequency of a harmonic signal using information obtained from digital readings during analog to digital conversion.

The standard logic of researchers in this situation is to adjust the analog to digital convertor (ADC) to the maximum sampling rate and get the maximum number of samples. For instance, let a trainee use an ADC at a maximum sampling frequency $f_s = f_{smax}$ = 175 Hz. As a result of measurements, a number of values are obtained, and on the basis of these values a students concludes that the original signal had the frequency $f_{01}$ = 75 Hz.

However, it is useful to show students that sometimes this statement is not true. An additional experiment with a frequency $f_s < f_{smax}$ should be performed. Figure 3 shows a number of values obtained at a sampling frequency $f_s$ = 125 Hz. The signal reconstructed from these values has a frequency $f_{02}$ = 25 Hz.

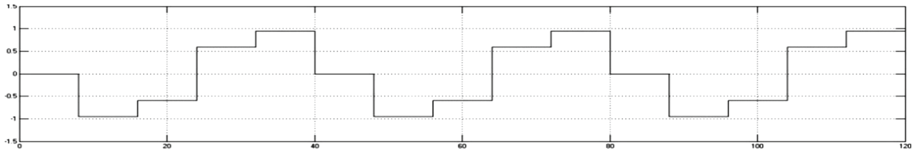

**Fig. 3.** The result of the experiment with ADC signal conversion

Differences in the frequencies of the reconstructed signal in the first and second experiments indicate that these frequencies are pseudo-frequencies, and that the frequency $f_{s\max} < 2f$, where $f$ is the real frequency of the signal under study determined by the formula $f = f_s - f_0$ [10]. Thus, the real frequency for considered example is 100 Hz. Thus, described method allows correcting the measurement result despite existing limitations of the equipment.

**Example 4** (Automation and Informatization of Scientific Research). As is generally known, information of daily and weekly cycles which is received as a result of processing a power system are used for obtaining knowledge about the load parameters in a forecast horizon. The forecast are given to students and they have to implement a strategy of advanced control and optimize operating modes of power system equipment.

**Example 5** (Automation and Informatization of Scientific Research). The Cyber Physical System of a remote laboratory can include false knowledge into the knowledge base of an investigated object. Models that provide such possibilities are considered in [11]. Students have to discover these contradictions by the methods of logical programming.

Consider an assignment about assessing completeness and consistency of available knowledge obtained from a cognitive control system of power transformer cooling. Parameters of the transformer control system are the load current L, the cooling system operating time T, the thermal resistance between a transformer and external environment R, and an oil or a transformer winding temperature θ.

These parameters are described by ternary variables and can take values from a set ("–", "0", "+") which means "decreases", "does not change", and "increases". For example, if L is equal "+" this is corresponded to a situation in which the load current of a transformer increases with time.

The result of assessing the quality of knowledge is also described by the ternary variable. A result Q can take values from a set ("–", "0", "+") which means "contradictory", "incomplete", and "consistent" respectively.

Students should develop a logical scheme for assessing the quality of knowledge. An example of such a scheme is shown in Fig. 4.

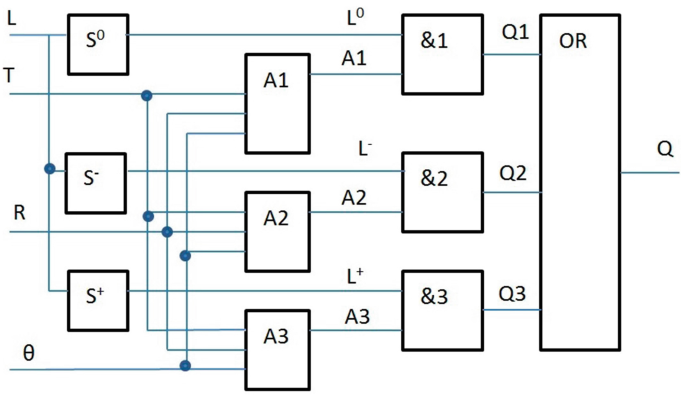


**Fig. 4.** Logical scheme for assessing the quality of knowledge

The following ternary logic elements are used in the circuit in Fig. 4: “$S^0$”, “$S^-$”, and “$S^+$” for selecting element values “0”, “–”, and “+” respectively; “A1”, “A2”, “A3” are elements for analysis of T, R, and θ combinations for the selected L; “&1”, “&2”, and “&3” are elements “AND”; “OR” is the “OR” element.

All elements of the circuit in Fig. 4, except A1, A2, A3 are described by known truth tables. For example, the table for $S^0$ element is shown in Table 2.

**Table 2.** Truth table for $S^0$ element

| Input | – | 0 | + |
|---|---|---|---|
| Output | – | + | – |

Elements A1, A2, A3 should take into account specifics of a subject area. For instance, the table for element A1 is shown in Table 3.

**Table 3.** Truth table for a ternary logical element A1

| T | – | – | – | – | – | – | – | – | – | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | + | + | + | + | + | + | + | + | + |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | – | – | – | 0 | 0 | 0 | + | + | + | – | – | – | 0 | 0 | 0 | + | + | + | – | – | – | 0 | 0 | 0 | + | + | + |
| θ | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + | – | 0 | + |
| A1 | 0 | + | 0 | – | – | + | – | – | + | + | – | – | – | + | – | – | – | + | + | 0 | – | + | – | – | – | + | 0 |

It is expected that students carry out the analysis of the circuit (Fig. 4) by using the programming language Prolog [12]. A fragment of the Prolog program is shown in Fig. 5. This fragment contains the description of `Q_logic(L, T, R, θ, Q)` of the circuit, and the specification of the ternary logic element $S^0$.

```
Q_logic(L, T, R, θ, Q)⇐OR(Q1, Q2, Q3, Q), AND1(L0, A1,
Q1), AND2(L-, A2, Q2), AND(L+, A3, Q3), A1(T, R, θ, A1),
A2(T, R, θ, A2), A3(T, R, θ, A3), S0(L, L0), S-(L, L-),
S+(L, L+).
So("-","-").
So("0","+").
So("+","-").
....
```

**Fig. 5.** Fragment of the Prolog program for the logical conclusion about the quality of given information

Prolog can create a list of situations as an answer to a question. Students may use: `? Q_logic (L, T, R, θ, "-")` - for a question "at what value of the variables L, T, R, and θ is the result should be considered as contradictory?" or `? Q_logic (L, T, R, θ, "0")` - for a question "at what values of the variables L, T, R, and θ is the result should be considered as incomplete?"

An example of a contradictory set of knowledge is the set L = "0", T = "–", R = "+", θ = "+" that is determined by the thermodynamic model of a transformer. If its thermal resistance R increases, and the load L is constant, than the oil temperature θ and the cooling time T must increase. However, in presented knowledge T = "–", that is the reason for the final answer Q = "–".

## 5 Conclusion

Cognitive control systems have be in the focus of learning process for future engineers. Studying models of such systems, methods of obtaining and transforming knowledge are effective ways which could be used in different curricula by organizing students' researches and practical works with objects of unknown structure ("black box"). The share of described in the article assignments should be increased, especially in courses where elements and components of complex cognitive control systems are studied.

The proposed solutions for engineering training are expected to be introduced in curricula that are being developed at the Zaporizhzhya National Technical University according to the framework of the projects of the European Commission within the program Tempus "DesIRE" and "ALIOT".

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## References


1. Automation and Informatization of Scientific Research. http://www.zntu.edu.ua/node/4219
2. Berry, F.C., DiPiazza, P.S., Sauer, S.L.: The future of electrical and computer engineering education. IEEE Trans. Educ. **46**(4), 467–476 (2003)
3. Chen, T.Y., Poon, P.-L.: Experience with teaching black-box testing in a computer science/ software engineering curriculum. IEEE Trans. Educ. **47**(1), 42–50 (2004)
4. Clocksin, W.: 1955-programming in Prolog: using the ISO standard. In: Clocksin, W.F., Vtllish, C.S. (eds.) 5th edn. p. cm. Includes Bibliographical References and Index. Springer (2003). 299 p
5. Frank, M.: Knowledge, abilities, cognitive characteristics and behavioural competences of engineers with a high capacity for engineering systems thinking (CEST). Syst. Eng. **9**(2), 91–103 (2006)
6. Hennig, M., Mertsching, B., Hilkenmeier, F.: Situated mathematics teaching within electrical engineering courses. Eur. J. Eng. Educ. **40**(6), 683–701 (2015)
7. Norhana, A., et al.: Lateral thinking through black box experiment among engineering Students. Procedia Soc. Behav. Sci. **60**, 14–20 (2012)
8. Olsson, G., Piani, D.: Cifrovye sistemy avtomatizacii i upravleniya [Digital Automation Systems and Control]. Nevsky Dialect Publ., Saint Petersburg (2001). 557 p. (in Russian)
9. Onderová, L.: Physics: a black box? Sci. Sch. Issue 12, 40–43 (2009)
10. Poliakov, M.A.: Set-theoretical models of functional structures of systems of cognitive control. Syst. technol. **3**(110), 16–23 (2017)
11. Poliakov, M.: Fuzzy regulator of cooling of power oil transformer on the basis of prediction of change of disturbing factors. Electr. Eng. Electromechanics **3**, 47–50 (2007)
12. Poliakov, M., Henke, K., Wuttke, H.D.: The augmented functionality of the physical models of objects of study for remote laboratories. In: REV2017 – 14th International Conference on Remote Engineering and Virtual Instrumentation, 15–17 March 2017, Columbia University, New York, USA, pp. 148–157 (2017)
13. Rowley, J.: The wisdom hierarchy: representations of the DIKW hierarchy. J. Inf. Commun. Sci. **33**(2), 163–180 (2007)
14. Rugarcia, A., Felder, R.M., Woods, D.R., Stice, J.E.: The future of engineering education. Part 1. A vision for a new century. Chem. Eng. Educ. **34**(1), 16–25 (2000)
15. Schwab, K.: The fourth industrial revolution: what it means and how to respond. Foreign Affairs (2015). https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution
16. Shuman, L.J., et al.: The future of engineering education. In: 32nd ASEE/IEEE Frontiers in Education Conference, Boston, MA (2002)
17. Smith, R.N., Craig, K.C., Theroux, P.: Development of a multidisciplinary core engineering experience for first-year students. In: 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis, IN (2005)

# Engineering Education Program Promoting the Profession

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**Abstract.** Many Engineering colleges have been facing the retention issue because of difficulties and lack of knowledge about what really means being an engineer. The first 3 years are particularly intense and hard. A possible way to overcome this period is to implement a new kind of course, more enticing and dynamic, which is the idea of COPEC's engineering education research team, to embed a course with a more interesting activity for students in the first year. Current students have access to multiple ways of learning. They make use of a range of learning sites, both physical and virtual. Currently, students are very smart users of modern technology and are well connected with the online world. They are already international. However, an international experience adds a lot to their reality. It also promotes an early picture of the profession in their minds. So, this program provides students the possibility to perform as engineers in an international environment. It is a project developed for a private university in order to foster the retention rate in their engineering courses.

**Keywords:** Retention · Project development · Real world work International skills · Innovations

## 1 Introduction

In the 21st Century, new paradigms of business, work and education have brought a greater need for workers with higher levels of education and specific skills to perform in advanced economies. It is a fact that under-skilled workers are disappearing, due to


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automation and low-cost labor markets abroad. Nations worldwide recognize (particularly in the western part of the globe) that it is urgent to train a larger number of engineers with technical knowledge, as well as with soft skills.

Engineering courses are full of important core subjects, however it is necessary to innovate and find ways to embed the curricula with important topics to attend the current global trends. Once engineering skills are internationally portable, leading to international mobility, which engineering can easily provide, and it is, in fact, an increasing trend. Intercultural skills, knowledge of languages and cultural prejudice management are very important, because opportunities are broad less and it is important to be able to adapt to any different cultural environment.

Another fact, which is not new, is that many engineering colleges have been facing the retention issue, due to the difficulties and lack of knowledge about what being an engineer really means. The first 3 years are particularly intense and hard. A possible way to overcome this period is to implement a new kind of course, more enticing and dynamic. This is one of the proposals of COPEC's engineering education research team: - to embed a course with more interesting activities for students, sooner in the first year. It is a short-term workshop to show students the possibilities of performing as engineers in a global environment – a project developed for a private university in order to reduce retention rate among students of engineering courses.

It is a 3 months' period, in the second semester of the 1st year, when the students have different classes, which are more dynamic, due to the mix of site visits, lectures, project proposals, travel period and project presentation. It is a very dynamic experience that provides students a clear view of what it is to be an engineer and what their possibilities for the future are.

The final goal of this project is to provide a sophisticated period to implement integrated environments for teaching/learning systems. It is in fact a way to reduce the evasion of engineering courses, showing a glimpse of what it is to be an engineer and the wide varieties of opportunities worldwide.

## 2 COPEC: Science and Education Research Council

COPEC – Science and Education Research Council is a multi-disciplinary organization, leader on advance science and its application to the development of technology serving society. It started its activity sixteen years ago and since then this organization has made a major contribution to the development of science and education, working to increase the best practices in several research fields.

Integration activities promoted by COPEC provide a qualified coordination and building partnerships, because COPEC is an organization that brings together scientists who share the mission of promoting and developing science, technology and education.

The objectives of COPEC are to promote professionalism, integrity, competency, and education; foster research, improve practice and encourage collaboration in different fields of sciences.

Contents, tools and services provided by COPEC, through courses, publications and consultations, with national and international experts, contribute to the promotion of the professional who wants to be privy of new achievements and service of men to technology.

COPEC enjoys respect and recognition internationally, characterized by the open discussion, the free exchange of ideas, respectful debate and a commitment to rigorous inquiry. Its IIE – International Institute of Education – is a bold and resilient source of innovation in higher education [1].

## 3 Contemporary Aspects of Education

Work environment worldwide has changed drastically, and today millions of professionals are also unemployed, even in advanced economies. On the other hand, businesses in economically advanced countries claim that they are often not able to find workers with the required skills. It is a fact that, this is a symptomatic dysfunction due to the structural changes that are transforming the nature of work and reshaping employment opportunities. This shows that organizations and policies are not keeping up with the changes in business practices and new technologies are defining what kind of jobs will be created and where they will be located. So there is a need for companies to redefine how and where different tasks have to be carried out, requiring new skills and new employer and employee relationships [2].

It is also important to attempt that globalization has been expanding access to low-cost talented professionals and creating a greater need for workers with higher levels of education and specific skills in order to perform in advanced economies. Under-skilled workers are disappearing, due to automation and low-cost labor markets abroad. In this world scenario, education and training should be seen as vital economic priorities by governments. However, it is still possible to observe some nations neglecting this, perhaps due to the lack of political interest other than electoral.

Although governments need to invest in the entire system, which builds workforce skills, in some places it is up to private initiatives to offer opportunities for young ambitious talented professionals, who can cooperate for a better future of generations to come. There is no better place than universities to offer these opportunities, pushed by the enterprises. It is important for nations to train highly skilled native-born citizens, as well as to attract highly skilled immigrants, in order to be competitive in a global scale and assure a future for the people [3].

Finally, government agents should be aware of the fact that, if there is no production system, there will be no financial resources to maintain the social assistance system. This idea of an innovative office will help to generate more quality services to improve industry service, as well as the production system, generating opportunities and jobs, which is a need everywhere in the world today [4].

## 4 The Course

Engineering is a challenging and dynamic profession, however, unknown mainly among the younger population. Some very bright students are advised to pursue medicine or Engineering. For those who choose engineering, however, the first three years are not charming and do not show what it is to be an engineer. It does not show students the very important work that they might accomplish in their lives. How much they will help human beings in daily life and how much engineering is important for the world and mainly the world people live today.

The proposed course promotes and allows students to get to know what it is to be an engineer. It is a short-term workshop which shows students the possibilities of performing as engineers in a global environment with the goal to reduce the retention rate in engineering courses.

It is a 3 months' period, during the second semester of the 1st year, when students have different classes, which are more dynamic due to the mix of site visits, lectures, project proposal, travel period and project presentation.

Besides the proposal of a project, which students have to develop, the course includes a short study abroad period, preferably in Europe. It happens in between the project proposal and the presentation of it after the trip, ending in October before the tests period.

The period abroad includes Technical, Academic, Social and Cultural activities, all very important to have a real experience, however, brief, and to understand a little about the lifestyle, history and culture of a country, elected by COPEC's education team.

All activities are performed within two weeks of intense work, generally in September. During this period, students also have lectures, visits to companies, universities, as well as social and cultural activities, which will provide students with a great experience and discover a different world.

It is a very dynamic experience that provides students a clearer view of what it is to be an engineer and what their possibilities for the future are. Students acquire inputs and ideas that instigate their imagination.

The period abroad can be done in more or less days, according to the needs of the course proposal for the period. Activities can be changed to fit the availability of organizations and people involved, as well.

Besides this period other activities are programed such as enterprises visits, as well as keynote speakers during the "Engineering Week". The idea is to invite successful engineers to speak about their path to where they are now. The speakers are invited to show mainly what the positive and negative points of the way are, what they had to change, give tips and hints etc. The idea is to provide more information to motivate students even more to keep going, finish the program and later to pursue success in their career.

## 5 Method

The team has chosen to design the course abroad in three phases:

Phase 1 – when students have preferably Industry lectures and are challenged to develop a project proposal in a specific engineering theme.
Phase 2 – when students go abroad for a short period.
Phase 3 – when students present their project proposal to a group of invited professionals who evaluate them.

The course is designed to introduce the world of engineering to the students and also to present them a bit of another culture, touring through several academic and business environments, developing cultural activities, exploring the history, experience local public services, where engineering plays an important role. The proposed course consists of an opportunity to improve the training of engineering students, providing them with an excellent experience, by meeting the practice of engineering in many sectors as well as providing them an experience abroad.

The students are graded and the best project group is invited to have an internship in one of the enterprises of the region, which are interested in having some of these students for a training period.

It is intended to enlarge the experience and send the students who have designed the best project abroad again for a short period to a university to work close to a group of researchers in their field of interest.

## 6 Details of the Period Abroad

The period abroad includes lectures, visits to companies, universities, as well as social and cultural activities, which will provide students with a great experience and allow them to discover a different world (see Fig. 1).


Fig. 1. Schedule for 2016/2017

The course can be done in more or less days according to the availability of the group of students. Activities can also be changed to fit the goals of the course. It is, in fact, a very flexible part of the course.

Within the academic activities, students have classes and participate in activities in different universities.

Technical activities include visits to some companies of the visited country. The lecturers are generally very technical in content, being some of them about administration aspects of projects and businesses generated from them.

Visits to laboratories and research centers are the main activities, developed in a pre-established framework, in accordance with the objectives of the program. In general, they follow the main theme developed by the students' groups in their project proposal. For example, "the development of senses for data collection in subway fluxes in rush hours", one of the main themes developed by the groups in 2015.

During social activities, students have the opportunity to visit some local meetings with other students in a friendly environment.

Cultural activities provide students with concepts of history and art, as well as the way of life, including guided tours, visits to museums, and other related activities.

All proposed activities take place in a way that students can experience the educational environment, business, culture and lifestyle of the country.

The proposed course consists of an opportunity to improve the training of engineering students, providing them with an excellent experience abroad and to acknowledge the international career that an engineer can develop. Besides the technical knowledge they acquire in site.

The course has the reputation of being demanding, rewarding and intense, providing a challenging educational environment by following high quality standards. The course is also developed to provide to the participants some free time to relax and enjoy the city and all it can offer.

Accommodations could not be better; students stay in comfortable hotels, with all the necessary facilities, in downtown areas of the cities [5].

## 7 Specific Objectives, Goals and Expected Results

The primary goal of the course is to foster curiosity and passion for the engineering profession and to provide engineering students an opportunity to experience different environments in the chosen profession. They will have a very impacting Engineering experience.

Furthermore, the course aims to:

- Improve the academic skills and leadership;
- Offer the opportunity to live in different cultures;
- Strengthen their career goals;
- Develop researching skills;
- Provide Travel experience;
- Provide a Global experience;
- Explore new opportunities;
- Enrich their life [6].

The project goals are:

- Providing an international academic experience;
- Make the students feel what it is to be an engineer;
- Assist in the development of critical analysis;
- Provide an overall experience.

The expected outcomes of the extra academic classes are:

- Dynamism for undergraduate careers;
- Long-term friendships;
- Technical skills and knowledge;
- Experience different cultures and histories;
- Enrichment of life;
- Valuing the profession [7].

It is important to provide students the core of any profession development, which are the values and sense of identity and about creating a culture of commitment and performance.

## 8 Partial Results

2016 is the third year of this 1st year effort program and the results are as follows (Table 1):

**Table 1.** 1st year effort program and the results

| Year | 1st year students number enrollment in Engineering | students number enrollment in the special course | % of enrollment rate |
|---|---|---|---|
| 2014 | 213 | 68 students | 31.92% |
| 2015 | 225 | 77 students | 34.22% |
| 2016 | 236 | 95 students | 40.25% |

The College conducted a survey among the students participating in this program and the results are the following (Table 2):

**Table 2.** Survey among the students participating in the Program (2014–2016)

| Questions | 2014 | 2015 | 2016 |
|---|---|---|---|
| Satisfaction with knowledge acquisition | 56% | 64% | 72% |
| Satisfaction with international experience | 62% | 68% | 69% |
| Satisfaction with acquired skills | 65% | 79% | 81% |

For the year 2017 (by the presentation of this work) the proposal is to have a complete chart with statistics about the retention rates acquired with this program so far. The decision relies in the fact that it is necessary at least three years of program to have significant data.

## 9 Conclusion

In the 21st Century, Universities are becoming the key actor in local development. It is clear that, along history, universities have become international organizations, not only receiving students from all parts of the world, but also through international research partnerships and providing opportunities to students. There is no doubt that this role has become imperative for countries which wish to keep up with a challenging and global educational and research environment. The best universities attract the best students and the best students make the university better.

The enhancement and promotion of students' quality training, as well as employability, brings financial resources, increases teacher's quality and promotes regional development, along with the future professional, no matter the field, but mainly in engineering.

And finally, in the global competitive environment that nations live, no matter the political scenario of the country, governments must invest in Science and Technology for the sake of national economy and development.

This course, in particular, promotes engineering courses, fighting the retention issue, providing the students a glimpse of what it is to be an engineer and increases their possibilities of developing an international career.

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## References

1. COPEC: Science and Education Research Council (2017). www.copec.eu
2. Heick, T.: 10 characteristics of a highly effective learning environment (2014). http://www.teachthought.com/learning/10-characteristics-of-a-highly-effective-learning-environment/
3. Smith, A.: Us Views of Technology and the Future, 17 April 2014. http://www.pewinternet.org/2014/04/17/us-views-of-technology-and-the-future/
4. Ciampi, M.M., Brito, C. da R., Vasconcelos, R.M.C.F., Amaral, L.A.M., Barros, V.F.A.: Science, engineering and technology innovation for global human challenges. In: American Society for Engineering Education Annual Conference 123, ASEE, Jazzed about Engineering Education, New Orleans (2016). https://peer.asee.org/26146
5. Ciampi, M.M., Vasconcelos, R.M.C.F., Brito, C. da R., Amaral, L.A.M., Barros, V.F.A.: Engineering for humanity in the 21st Century: challenges and opportunities. In: IEEE Frontiers in Education Annual Conference 46, FIE, The Crossroads of Engineering and Business, Erie (2016)

6. Ciampi, M.M., Brito, C. da R., Vasconcelos, R.M.C.F., Amaral, L.A.M., Barros, V.F.A.: Shift for engineering horizons. In: European Society of Engineering Education Annual Conference 44, SEFI, Engineering Education on Top of the World: Industry University Cooperation, Tampere (2016). http://www.sefi.be/?page_id=7081
7. Ciampi, M.M., Brito, C. da R., Amaral, L., Vasconcelos, R., Barros, V.F.A.: Engineering challenging entrepreneurship practice. In: Auer, M.E., Guralnick, D., Uhomoibhi, J. (eds.) Interactive Collaborative Learning: Proceedings of the 19th ICL Conference, vol. 2, pp. 444–452. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-50340-0_39

# High Quality Engineering Program Achievement

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**Abstract.** Buildings and bridges are often the first constructions that come to mind, as they are the most visible creations of structural engineering. Civil engineers design roads, railways, subway systems and airports. And there are also less visible designs, just like every time people turn on a water tap waiting for the water to flow, without thinking that civil engineers made it possible. Finally, civil engineers are still of fundamental necessity for the construction of the civilized world. The goal of this paper is to describe a program, specially designed for a private engineering school, whose aim is to become the best one in the region, once there are other universities at the same level competing for students. COPEC – Science and Education Research Council's Engineering Education Team has designed a new engineering program, knowledge centered and specially challenging, which integrates classical engineering approaches and real experience, in order to achieve a high level of engineers ready to perform as professionals or researchers. It aims to form the Engineer – a professional that is capable to learn for life and be creative in many ways.

**Keywords:** Learning/teaching tools · Best practices · Work market Intellectual skills · Knowledge-centered

## 1 Introduction

This is the digital era, characterized by the amazing abundance of information that somehow presents a permanent overload of information. It is a fact that almost all information, and unfortunately misinformation, is available, at any time, on the fingertips of


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any user of a digital device connected to the Internet, and there are currently billions of these devices being used around the world. One of the tasks of educational institutions today is to make good use of this abundance of information by providing quality education, centered on knowledge. Knowledge which is pertinent and which allows the future professional to discern what serves and what does not serve and make use of this knowledge to produce, transform and improve life and work of man. What can institutions do to form the equipped engineer for the future? One answer can be: if students are taught the skills of learning, then they will continue to learn on their own for the rest of their lives. How is this possible? By the well-walked path of "tried and proven" — the classical method of educating engineers. It means sufficient mastery of the basic tools of science and mathematics to address technological problems. This can be achieved through classical education, not as synonym of Christian education, but as an education with solid basis of knowledge in basic sciences and basic sciences of engineering. Students will then finish their course equipped with the right tools and a strong capacity of learning. Classical education, in this sense, is a life-long process of applying the "tools of learning" - tools that are skills entailed in basic sciences, engineering basic sciences, and specific of engineering, which travel with the student through her/his career as a professional or as an academic. In other words, the market seems to be ready for those who obtain a general engineering education and develop adaptable skills, which will serve them, while their world continues to evolve [1].

The integrating part of the program comes from internships and practical projects, which are relevant for both: student's studies and the real work scenario. The internship and the project offer opportunities for students to take the skills they are developing in the classroom to the real world. So, School provides internships in companies, in the field of student's choices, during the fourth and filth years of college. They are then, at that time, more prepared to face these challenges [2].

The authors of this paper use "classical education" meaning knowledge centered education and refer to "classical method of educating engineers" as the same kind of approach. It refers to the choice of in-class classes, with face-to-face interaction, strong and deep study, mainly in mathematics and physics, as the basis for the quality education that provides the tools that conception and application engineers need. More than ever, education means cultural, economic, individual, philosophical, scientific and social advancement. This means that education is the mean to develop the mind for the betterment of the individual and consequently also society. And in the present world scenario, advances in science and technology mean that the world will continue to change rapidly, so that the knowledge learned by students in specific careers, even in engineering, will have a short lifespan. In contrast, those who achieve a general engineering education will develop adaptive skills, which will serve them while their world evolves.

## 2 The Value of a Proper Formation

Specific formation, at a time when engineering practice and engineering systems are becoming larger and more complex, involving components and processes from widely dispersed fields, is very questionable. There are educators who believe that the most important human/society problems of our time will not be addressed through disciplinary specialization, but rather through approaches that can integrate many different areas of knowledge. This fact, coupled with the growing competitiveness of higher education institutions in the region, has led an engineering school from a private university to invest in a new civil engineering program, instead of opening a new program in another field, since this is the most required course by young people in the region. Therefore, a way to overcome the difficulties of the hard competition and external evaluation of programs, the University has hired COPEC – Science and Education Research Team for Engineering Education, which has designed a program, which is knowledge centered and specially challenging. It is a program that integrates classical engineering approaches and real experience, in order to achieve a high level of engineers ready to perform as professionals or researchers. Their goal is to train Engineers able to learn for life and to be creative in many ways. The proposed program has been specially designed, and its goal is to become the best one in the region, (which still needs a lot of effort to achieve this goal), in order to attract more students, due to the competition among universities, that despite being a relatively small region has five other Universities offering the same program of civil engineering. Added to this, there is also the effort to face the external evaluation process by the Ministry of Education, which is extenuating and time consuming [3]. It is expected that this program will put the university's engineering school among the best ones in the State, competing with many others, which have been historically considered the best.

## 3 The Ever Timeless and Valuable Classical Engineering Education

Still, classical/general education (here as opposed to progressive education or student centered, etc.) is the education that has over 2500 years of history in the West and that has been working very well due to its characteristics of being timeless. It began in ancient Greece, was adopted widely by the Romans, reduced after the fall of Rome, made a slow, but recovered steadily during the Middle Ages, and was again brought to perfection in the Italian Renaissance. The main objective of classical education, at any level, is to form the Person = citizen with values and ethics, in accordance with timeless intrinsic values; it is a very effective way to form free conscious citizens, as opposed to controlled misinformed citizens. The classic education states, essentially, that human beings are intelligent beings, which mean that human beings want to know things, more specifically to know what things are and how they work. It is primarily focused on knowledge and not student-centered [4].

In Universities, the classical/general education demands self-discipline and, no doubt, that it produces intelligent curious young professionals, who can think, calculate, analyze, understand, solve problems and follow through a wide range of perspectives. It is systematic and rigorous; it has goals and a method to reach the goals. It provides future professionals the tools to learn and to adapt to the new work environment, as well as to the mutant work market of this millennium.

Looking back to Human History, the classic engineering formation has produced engineers who were responsible for the appearance of weapons for defense, fortifications, roads, bridges, canals, tools, etc. Following its development as an important human achievement in formal education, in ancient times. In the eighteenth century, the first engineering schools emerged in France. They are: the École des Ponts et Chaussées (1747), the École de Mines (1783) and the École Polytechnique (1794), it was the period when Science married Engineering. They all belong to the group of French Schools, that constitute mostly the so-called "generalist" Grandes Écoles, and the leading ones, of these groups, constitute the major part of the French scientific elite education system [5]. Science research development has been showing that research work is not based on a top-down, command-and-control hierarchy anymore, because due to this new virtual and complex system, scientists combine and recombine in research teams, based not on academic discipline or institutional affiliation or geographic location, but on the unique requirements of the problems that they want to address. It means that researchers do not have to be in the same place of their collaborators, nor have they to be in the same place as the problems they seek to solve. There are also international networks, which are more important to individual faculty members, than their departmental or institutional ties, since this network enlarges the possibilities of research and career success [6]. It is important to point out that, the time is coming, in which most people will have a number of jobs before middle age (around 53–60 years, according to the new paradigms of aging in 21st Century) and in which many jobs have not yet been developed; the question is: how can educational institutions form or train in a manner that may not yet exist? The classical/general education curriculum provides an answer.

## 4 The Classical Education in Civil Engineering – The Answer for Times to Come

These are challenging periods of constant changes; around the year of 2050 people's age for retirement will reach 72 years; it is estimated that today's college students will have over four jobs before the age of 30, and over ten jobs before they are 40. In fact, many engineering graduates will work for small high-tech companies or consulting services companies, moving from organization to organization and from role to role, frequently. To adapt to this new work environment, engineering graduates must accept the personal responsibility for their lifelong learning process, through acquiring effective self-learning skills besides the management of their careers, since it is very hard and difficult to oversee the future. Regarding this, what is missing in the current engineering education curriculum, increasingly crammed as it is, with demanding technical material, is the opportunity for a truly quality education (education that empowers young students and prepares them to deal with complexity, diversity and change, providing them with broad knowledge of the wider world, e.g. science, culture, and society) as well as in-depth study in a specific area of interest, designed to enable young students to develop their deeper intellectual skills, necessary to adapt to a world characterized by continuous change. So, Classical Education is a way to enable students for these new work market demands.

Classical/general education can be defined as a curriculum for broadening the mind —one of the hallmarks of an educated person—and as a way to prepare for active participation as a citizen. At present time, there is a sense that classical/general education should focus in key attributes that employers value as needed by a generally educated person: critical thinking, writing, speaking, arguing, researching, and mathematical reasoning. In addition, to introduce a broad variety of subjects, classical/general education should exercise skills and habits of mind. After the Second World War, with the cold war, and the run for the moon, education suffered a big change, added by the enlargement of students attending University. These changes were necessary, however, due to the challenging and mutant educational environment, as well as the global market and the scientific and technologic new achievements, it is rather difficult to figure out what kind of engineers' training will be necessary. In order to face the new challenges, the classical engineering training is an approach that provides new engineers the right tools to perform and to learn for life [7].

There are two facts that have driven engineering faculties to engage in the improvement of their programs in every field: first, private universities are struggling to attract good students for their programs, since it guarantees the continuity of colleges and programs, therefore, also their employees. Besides this, there is the external national evaluation that programs and colleges have been facing nationally, both of this facts push schools and colleges to enhance the quality of their programs. Therefore, to attend the necessities of an engineering college of a private university, COPEC's team has chosen to propose the pursuit of a classical/general education approach for the civil engineering program and so form the "Engineer". The engineer who has knowledge and self-taught skills - a professional who can think, calculate, analyze, understand, solve problems and follow through a wide range of perspectives, including international competitiveness, social, economic and sustainability issues, among others. It is a way to attract good students to their programs, as it ensures the continuity of colleges and programs. The proposed program by COPEC is, essentially, what says a famous and very appreciated Chinese Proverb – "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime". The specific civil engineering program started in 2014 and the enrollment was low, comparing with previous years. However, after three years, the results have been very positive, taking into account the trend of engineering programs, choices of younger generations and the universities' competitiveness for students in the region.

## 5 Global Market and Engineering Education for Future

It is possible to state that civil engineers are, in a certain way, managers of the natural environment and its resources, (such as flood control, landslides, air and water pollution), protecting our environment for a sustainable future, innovating and integrating ideas and technology in the public and private sectors. They are the managers of risk and uncertainty caused by natural events, accidents and other threats; and also leaders in discussions and decisions that shape environmental policy and public infrastructure. The proposal of a classic engineering program came as a response to develop a new educational approach with the goal of strengthening a civil engineering course that saw its enrollment declining, each year, despite the work market demands.

The key elements of the program are:

- have a well-conceived, coherent, sequential curriculum;
- have all courses with strong and pertinent knowledge;
- adjust other parts of the education system of the program to support the goals of learning;
- provide teachers with a carefully conceived curriculum, filled with challenging texts and materials;
- provide information to students about where they are going and how they are going to get there.

Students are challenged to acquire the knowledge that they really need to become engineers; a professional capable to do any work and overcome the unpredictable future, when it is becoming difficult to anticipate the new professions and opportunities that will be needed [8]. The development process of this program is long and implies many changes, including teachers trained for the program and for achieving the main objective, which is to foster students' analytical and verbal skills, creativity and innovation, entrepreneurship, the appreciation of complexity and ambiguity and leadership, very important for the formation of the engineer of this millennium.

The curriculum is organized in order to provide students with basic sciences courses, taught during the first two years; followed by basic sciences courses of engineering, deployed during the second and third years, and the specific courses of engineering (see Fig. 1), in this case, civil engineering, with emphasis in concrete constructions and eco building construction (following the trend of sustainable buildings – energy efficiency and use of low emission of $Co_2$ materials) [9].

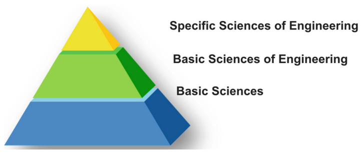


**Fig. 1.** Structure of the program

Figure 2 shows a block of different courses that were added and that have been taught in a period that has been named as Pre-Program, which happens two weeks prior to the year schedule, when students have classes of Language usage, Instrumental English (usage of technical English), Mathematics (review of high school content) and Psychology (aspects of competitive and demanding pressure environment).

So the program design is as follows:

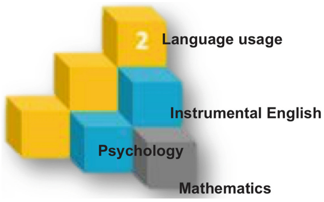


**Fig. 2.** Block of different courses that were added in a period that has been named as Pre-Program

## 6 The Curriculum

Table 1 shows a chart of the basic cycle curriculum, that covers seven subjects in the first semester of the year of admission of the student in the Civil Engineering course and eight subjects in the second semester, totaling 27 credits in the first semester and 28 in the second semester. The content of subjects is taught deeply and with intense exercise sessions. It starts in the pre-program and lasts for all years.

**Table 1.** Basic cycle curriculum

| | Discipline | CC | CW | TC | OC |
|---|---|---|---|---|---|
| 1st Semester | General Physics for Engineering I | 4 | 0 | 4 | |
| | Experimental Physics for Engineering I | 2 | 0 | 2 | |
| | Introduction to Engineering Computing | 4 | 0 | 4 | |
| | Differential and Integral Calculus for Engineering I | 4 | 0 | 4 | |
| | Linear Algebra for Engineering I | 4 | 0 | 4 | |
| | Design for Engineering I | 2 | 0 | 2 | |
| | Introduction to Engineering | 3 | 0 | 3 | |
| | General Technological Chemistry | 4 | 0 | 4 | 27 |
| 2nd Semester | General Physics for Engineering II | 4 | 0 | 4 | |
| | Experimental Physics for Engineering II | 2 | 0 | 2 | |
| | Numerical Calculus | 4 | 0 | 4 | |
| | Differential and Integral Calculus for Engineering II | 4 | 0 | 4 | |
| | Linear Algebra for Engineering II | 4 | 0 | 4 | |
| | Design for Engineering II | 2 | 0 | 2 | |
| | Mechanics I | 4 | 0 | 4 | |
| | Introduction to Materials Science for Engineering | 4 | 0 | 4 | 28 |

**CC** – Credit class **CW** – Credit work **TC** – Total credits **OC** – Overall credits

## 7 First Results

Table 2 shows the results of the third year of this Civil Engineering program.

**Table 2.** Civil engineering program

| Year | Total of students that have entered in the Civil Engineering Program | Number of students of civil engineering that have opted for the Classical Engineering Program | % of enrollment rate |
|---|---|---|---|
| 2014 | 180 students | 89 students | 49.44% |
| 2015 | 180 students | 100 students | 55.56% |
| 2016 | 180 students | 136 students | 75.56% |

Table 2 is only based on the enrollment number of students in the first and following years of the program.

Teachers should:

- Plan and deliver lessons in an interesting and effective manner according to the curriculum;
- Design pertinent course material for lessons;
- Monitor and maintain student's high morale and motivation;
- Monitor students' performance and render support as required;
- Encourage students' involvement in classes;
- Assist with practical activities, when needed.

## 8 About the Expected Outcomes

The program proposes specific learning outcomes and competencies such as:

- Applied learning: used by students to demonstrate what they can do with what they know;
- Intellectual skills: used by students to think critically and analytically about what they learn;
- Specialized knowledge: the knowledge which students demonstrate about their individual fields of study;
- Broad knowledge: transcends the typical boundaries of higher education students and encompasses all learning in broad areas through their solid knowledge in basic sciences and specific for engineering;
- Civic learning: enables students to respond to social, environmental, and economic challenges at local, national, and global levels [10].

## 9 Discussions and Conclusions

There are no surveys on this program to determine if this group of students is better trained and/or has better skills, but it is estimated that during the internship period, they show better knowledge of mathematics, which seems to enhance their performance. By better performance it means that students can cope better with the challenges and difficulties of problem solving and have a better understanding of the importance of searching for the best solutions. So far, the design and implementation of this program has been very positive. The first group of students, who will graduate in 2018, students who are in internship at their 4th year, have showed better performance when compared to the other programs, which is a first step towards success. It means that the students have better grades, especially in the second and third years of the program, so far. The Pre-Program, in special, has a good effect on students, since it provides them some elements that they can use, such as Psychology and technical English. The internship period, recommended in the 4th year of the program, has just started and the engineering college has been working to help students to find good training placements. It is crucial to advise them and to ensure proper conditions, in accordance with the law, in order to avoid waste of time and possible misuse of qualified labor.

This program, which is knowledge cantered, is responding very well in terms of students' enrolment and it is necessary to develop a survey to find out what are the elements that make students opt for this kind of education: the different approach, the strong knowledge basis or the possibilities of performing in any field of civil engineering, since the present job market is mutant and challenging. This shall be the next step for 2017, to develop a survey which will allow us to refine the program and provide an input about the most relevant aspects of the program. Results shall be known at the beginning of 2018.

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## References

1. Knowles, M.S., Holton III, E.F., Swanson, R.A.: The Adult Learner: The Definitive Classic in Adult Education and Human Resource Development. Routledge, New York (2014)
2. de Vries, M.J., Gumaelius, L., Skogh, I.-B.: Pre-university engineering education. In: Pre-university Engineering Education, pp. 13–25. Springer (2016)
3. Amat, S., Busquier, S., Jose Legaz, M., Ruiz, J.: Unifying the classical approach with new technologies: an innovative proposal for teaching mathematics in engineering. Int. J. Interact. Multimed. Artif. Intell. **3**(4, SI), 17–19 (2015)
4. Altbach, P.G.: What higher education does right: a millennium accounting. Chang. Mag. High. Learn. **32**(4), 52 (2015)
5. Wankat, P.C., Oreovicz, F.S.: Teaching Engineering. Purdue University Press, West Lafayette (2015)

6. Pâmîntaş, E.: Higher Technical Education - Research vs. Education. Technique of Teaching, Between Classical and Modern, vol. 66, no. 1. ACTA Universitatis Cibiniensis (2015)
7. Brito, C. da R., Ciampi, M.M., Vasconcelos, R.M., Amaral, L.A.M., Barros, V.F.A.: Engineering adventure for youth generations. In: 2016 ASEE Annual Conference and Exposition Proceedings (2016)
8. Brito, C. da R., Ciampi, M.M., Barros, V.F.A., Amaral, L.A.M., Vasconcelos, R.: Engineering the engineering program: the year of discovery. In: 2016 IEEE Frontiers in Education Conference (FIE), pp. 1–4 (2016)
9. Brito, C. da R., Ciampi, M.M., Amaral, L.A.M., Vasconcelos, R., Barros, V.F.A.: The year of discovery. In: 44th SEFI Annual Conference (2016)
10. Brito, C. da R., Ciampi, M.M., Amaral, L.A.M., Vasconcelos, R., Barros, V.F.A.: Creating new learning environment to foster enrollment in engineering programs. In: Auer, M.E., Guralnick, D., Uhomoibhi, J. (eds.) Interactive Collaborative Learning: Proceedings of the 19th ICL Conference, vol. 1, pp. 455–463. Springer, Cham (2017)

# Academic Performance Assessment Based on Accumulative Rating System at Polytechnic University

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**Abstract.** Continuing change of quality requirements in engineering education makes it necessary to substantially reform the educational process in technical universities. This change should be built on the basis of identifying the conditions in which the competences of the future professionals can be formed and developed. Effective implementation of these processes requires continuous monitoring of the learning outcomes. But traditional final control, which is still widely used in the higher educational institutions, is insufficient and does not allow applying corrections in the learning process in a timely manner. The resolution of this contradiction can be made possible by introducing an accumulative rating system (ARS) to evaluate students academic performance, using weighting factors, records of timing labor costs and modified website to host individual learning outcomes. This study deals with the application of the above mentioned tools for assessing students academic learning outcomes in the teaching of social and arts disciplines at polytechnic university.

**Keywords:** Academic performance · Continuous monitoring of outcomes Final control · Rating-based accumulative system · Weighting factors Timing labor costs · Polytechnic students

## 1 Introduction

The relevance of the study is related to changes in the requirements for assessing the quality of the educational process in the higher technical school. The international and national standards of engineering education, built on the principles of a competence approach, imply the use of a new system for monitoring the progress of future engineers - the accumulative rating system (ARS). ARS is one of the main instruments of current and final quality control of training [1]. In the transition of higher education to new educational standards, special attention is also paid to encourage internally motivated student's learning activities. It determines the leading principle of modern higher education - the principle of cooperation, which implies that the student should be as active as possible, and the teacher fulfills more the advising and coordinating function.

However, the traditional control system, which is dominated by the final control conducted at the end of the semester with the use of a four-point assessment system,


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developed in students a stable stereotype of episodic (on the eve of the session) activity in educational process. The teacher in these conditions is overloaded, the quality of evaluation and control is reduced. Such organization of the educational process leads to the formation of external motivation in future engineers and an external locus of control. In addition, the score is often perceived by students as biased. Ultimately, this leads to a decrease in the effectiveness of the educational process [2].

## 2 Review

The system of knowledge control in Russian universities to a certain extent contradicts the modern world requirements for the training of highly qualified professionals. Classic forms of control of knowledge (examinations, testing, control works, etc.) do not provide sufficient objectivity. It assumes the passive role of the students in their own professional development and have a low educational potential.

In the Russian pedagogy, considerable theoretical and practical material has been accumulated to improve the system for evaluating and monitoring the effectiveness of the learning process (I.I. Kulibaba, I.Ya. Lerner, M.N. Skatkin, and others). Control should be subjected to knowledge, skills and abilities in the dynamics of their development, which implies the consistency and systematic pedagogical control.

Using the rating in training, as many researchers note, promotes the transition from reproduction to productive thinking (S.M. Usmanov, A.A. Petishev, P.A. Yatsyavichin, M.A. Choshanov and many others). The rating is translated as “evaluation”, but in our study it is considered as the sum of the assessments that the student accumulates throughout the semester. Rating is the place (position) that the student occupies in the group in accordance with the number of rating units – TLC (temporary labor costs). A rating is an individual summary indicator of a student’s knowledge level and his attitudes toward the learning process, established at each stage of the current, boundary and final control of knowledge. For each completed type of educational activity the student receives an evaluation in the form of a score. Thus, the rating in its basis provides systematic, motivated, active, creative work of both students and teachers.

Proceeding from this, we use the term - score-rating accumulative system (SRAS). Instead of points, our system takes into account temporary labor costs (TLC), which assess any student’s academic activity. This activity is evaluated by the time spent by students and adjusted, if necessary, by the teacher using a weighting factor (WF - from 0.5 to 2.0).

The ARS is a system based approach aimed at the setting up and integration of students’ TLC in a regulated scale centered on the results of all types of learning activities when mastering basic educational programs. The main tasks of this system can be indicated as increasing the motivation of students; quality of learning; competitiveness in studies; the level of organization of the educational process; training co-operation, as well as stimulating systematic work and reducing the impact of random factors when passing tests and examinations.

The ARS assessment includes the target, organizational, substantive and methodological components. The target component assumes, as a criterion, that the assessment consists not only of educational results, but also the dynamics of the student's personal and professional development. The organizational component involves the development of a clear task verification plan, its joint discussion with group coordinators and with all students.

The content of the SRAS filling includes various tasks as reproductive (tests, trials, terminological dictations, etc.), as well as creative and research (essay-reflection, essay, mini-projects, research projects, etc.). The ARS covers the entire content of the course, taking into account the universal, broad professional and specific professional competencies formed during its study.

Methodical support includes clear, accessible instructions and recommendations for the fulfillment of tasks, the selection of interesting productive forms of control that promote the development of students' motivation for educational, practical, project, research activities, as well as for future professional activities.

The following aspects were highlighted as the advantages of ARS:

- stimulating potential, its ability to involve students in the competition for mastering the competencies of the specialty and profile;
- convenience - as a universal tool for working with student groups of different numbers;
- transparency, the provision of regular, open and accessible for students' perception and understanding of their level of academic achievement;
- the ability to increase students' awareness of the criteria for assessing achievements and, accordingly, to adjust their work;
- the ability to objectively assess the work of the student as a whole;
- the ability to provide the student with the opportunity to independently allocate their working time.

As negative aspects of ARS, it is possible to specify:

- inapplicability of the ARS for so-called unorganized students, characterized by a low level of academic discipline, often missing classes that fail to perform tasks on time;
- the risk of shifting the students' value priorities from mastering competences to showing an interest in recruiting a certain number of TLC as an end in itself.

## 3 The Study

### 3.1 Objectives

The purpose of this study is to test the effectiveness of the methodology of using the SRAS in training future engineers in psychological and pedagogical disciplines.

Main objective:

1. Determine the theoretical and methodological approaches to the introduction of SRAS in the educational process of a technical college.
2. To develop a methodology for the application of the ARS in the teaching of psychological and pedagogical disciplines.

3. Investigate the changes in activity in the educational activity of students who participated in experimental work with the aim of identifying criteria for assessing and verifying the effectiveness of the developed model.
4. Develop a technological map, website, fund evaluation tools discipline.

### 3.2 Methods

Methods of research: observation, testing, the method of expert evaluation and analysis of the activity results; Method of data processing.

Applied techniques:

1. Map of time recordings of students in the study of discipline.
2. Monitoring of changes in the total number of TLCs at the current and final control.
3. Monitoring the ranking of students throughout the semester.

### 3.3 Participants

The study involved 160 students of Peter the Great St. Petersburg Polytechnic University, who studied the discipline “Pedagogy and Psychology”. Of these, the experimental group consisted of 83 people, the control group - 77 people. Experimental work was carried out for 1 year. In the experimental groups, training was conducted using the SRAS, as well as the website of the discipline. In the control groups, progress monitoring was conducted in the traditional form (the system of tasks for independent work, the final offset at the end of the semester). At the same time, 95% of the participants in the experimental work did not have the experience of training with SRAS. 5% had experience working with the SRAS when studying abroad. 85% of students did not hear about SRAS, 15% - heard about the application of SRAS in Russian and foreign universities.

### 3.4 Data Collection

Research was carried out in several stages:

- 1st stage (May – June 2016) - analysis of theoretical material and development of the learning process methodical base.
- 2nd stage (September – December 2016) - teaching the discipline “Psychology and Pedagogy” according to the traditional method in the control group.
- 3rd stage (February – April 2017) - conducting of formative experiment, using the SRAS methodology in the experimental group.
- 4th stage (April 2017) - carrying out of the final diagnostic.
- 5th stage (May 2017) - the processing and interpretation of data.

Discipline “Pedagogy and Psychology” includes 72 h (48 h of classroom work, 12 h of independent work and 12 h for preparation and delivery of credit). Auditor and independent work of students in the experimental and control groups had the same content. However, the control group did not take into account the activity of students during the training. The deadlines for the commission of independent works were only indicated. The test took place in the form of an oral response to theoretical questions.

Techniques:

1. Map of time recordings of students in the study of discipline and monitoring changes in the total number of TLC s with current and final control.

In the experimental group, a criterion was introduced for students' assessment - temporary labor costs (TLC), which take into account any activity of the student in time spent studying this discipline. The course is designed for 72 TLC, fulfilling which the student can get a credit. In the control group, TLC was registered during the expert evaluation of the teacher (without reporting to the students). The average activity of students in the classroom was assessed, the time for handing over the independent work and their correctness. This made it possible to carry out a comparative analysis, collected by the TLC in the control and experimental groups.

In the experimental group, a technological course map was compiled containing tasks for the entire semester. The assignments consisted of compulsory and optional tasks. At the same time, we used the methodological recommendations of Andreeva [8]. The technological map, together with the necessary explanations, was presented on the website. When creating a website, we used the teaching tool Kudinov [9].

When compiling a technological map of discipline, we proceeded from three types of activity of students: (1) attendance - 32 h of lecture and 16 h of practice (48 TLC); (2) activity in the classroom (questions on the lecture, work in small groups, in pairs of replacements, messages, reports, etc.); (3) independent work - work with terms, personalities, reading of primary sources, watching films, writing essays, conducting professional and pre-professional tests (and their analysis), reconciliation of completed work (at least 3), preparing abstracts, reports, etc.

We consider it an important condition - clarity, transparency and publicity of the criteria for evaluating any activity of students (both classroom and independent), so in the technological map each type of independent work is described in more detail. The teacher reserves the right to expertly evaluate the work of students with a weight factor (0.5–2.0), thanks to which TLC spent by students can be reduced by a factor of 2 (0.5) and increased by a factor of 2 (2.0), if the teacher considers this work to be in accordance with the stated criteria.

2. Monitoring the ranking of students throughout the semester.

Every two weeks (closer to the end of the semester every week) a rating was put on the students recruited by TLC students to the site. In this we were helped by the students themselves - the elders, who monitored the correctness of their TLC comrades, carrying out basically a coordinating function, not a supervisory function, and a general coordinator-administrator of the site that supported his work capacity. It should be noted that visits by the students to the control group of the site, especially after rating, were very high, and in December (by the end of the semester) it reached 100 visits per day (with a total number of 83 people).

The site exhibited not only a rating, but also a technological map of the course with explanations, as well as texts of the main topics of the course, questions of two boundary controls, so that students who missed this lesson could fill in the corresponding gap. At the same time, they were able to pass the topics of missed classes, test tasks of boundary controls not only to the teacher, but also to those students who successfully coped with the assignments and were appointed specifically for this purpose by the teacher.

By the end of the semester, the final rating of the student was formed and the number of TLC recruited was taken into account, which allowed to set the test.

## 4 Results

In the course of the study, the following results of taking into account TLC in the control (CG) and experimental (EG) groups were obtained (Figs. 1 and 2).

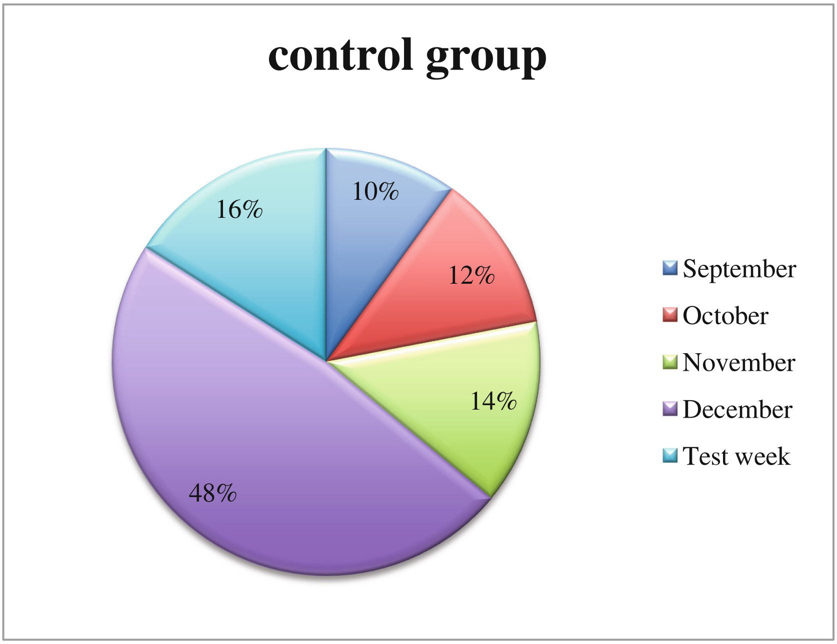


**Fig. 1.** Distribution of the total number of accumulated TLC for a semester by months and during last (reporting) week

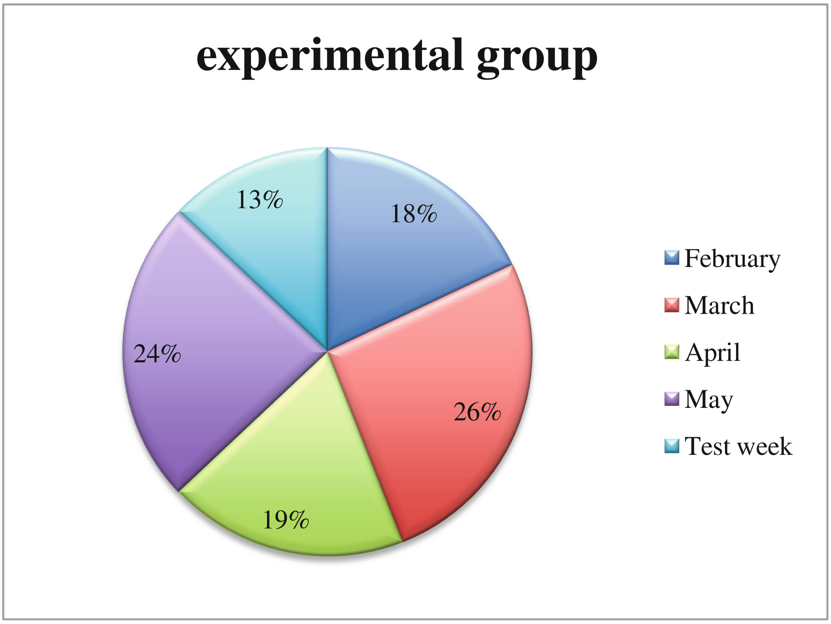


**Fig. 2.** Distribution of the total number of accumulated TLC for a semester by months and during last (reporting) week

It can be seen from the graphs that the maximum number of TLC s in the control group was scored at the end of the semester (December and the test week). This is due to the fulfillment and submission of tasks for independent work. Activity in lecture and practical classes is quite low.

In the experimental group, the total number of TLC s received by students is distributed mostly uniformly. The average number of TLC in the whole discipline (total 5195) per student (83) is 62.5 TLC, that is, exceeds the required level (60 TLC) required for obtaining the credit.

In the experimental group, over 60 TLC s were enrolled by 36 students (44%) and 12 students scored from 54 to 59 (15%). Thus, our hypothesis (30–40%) was not only confirmed, but also exceeded our expectations (almost 50% of students are ready to get credit automatically, that is, they have successfully mastered the course).

After the end of the semester before the credit week, we allocated three samples of students (10 people) in the experimental group from the general rating, which had a higher, lower and average ratings to show the activity of the students during the semester. The sample-1 - 10 students who scored the highest rating (76–86 TLC), the sample-2 - 10 students - the average rating (55–60 TLC) and the sample-3 - 10 students, which at the end Semesters had a lower rating (12–37 TLC).

Many authors who have long used SRAS in the teaching of humanitarian disciplines [10] note that the rating system gives the best result in “strong” groups, and weak students are less supportive. We agree with this statement, our practice also confirms this. On our sample, the groups are not the same, there are “strong”, and there are “weak”.

Presenting, for clarity, all three samples on one graph, we can draw the following conclusions. The group of the top and average rating differ from each other mainly by independent work, and not by attending classes. At the same time, the entire middle group almost scored the necessary number of TLC s for offset (60), that is, practically all students of this sample can get credit.

The existence of independent work is an obligatory part of the discipline, as well as the activity of students in classroom activities. Distribution TLC initially arranged so that only one visit to classroom classes can not recruit the necessary number of TLC. In our case, if the student attended all classes (including 2 margin controls) and did not show activity, did not perform independent work, he can only dial 48 TLC. But this is an ideal situation. Practice shows that 100% of attendance is not even for students motivated to study the discipline. On average, attendance fluctuates between 60–80% (28–38 TLC).

The most indicative sample is where the students with the lowest rating are represented. The average value of TLC for this group is 28. And it turns out that these students can get the necessary number of TLC only through independent work. That they do on the week of the count and on the very test, which we hold in an interactive form.

Thus, with the introduction of the SRAS, the student is forced to orient himself both to the manifestation of his activity in lecture and practical classes, and in performing independent work. This is one of the tasks of introducing the SRAS - creating conditions for the presentation of various types of student activity, that is, for observing the principle of individualization. And we believe that SRAS is coping with this. Especially if it is applied from the beginning of the training courses.

And in this way, you can destroy the stereotype of students that you can start studying right before the session. Another option for solving this problem can be the introduction of short-term courses (from 3 weeks to 2 months), which end in credit. This can be done within the framework of the course, breaking it into sub-courses (modules).

## 5 Conclusions

The study showed that the use of SRAS in the teaching of psychological and pedagogical disciplines in a technical college leads to increased student activity, the formation of a sustainable motivation for learning activities, the development of abilities for self-control and reflection in future engineers.

The total number of temporary labor costs (TLC) received by students exceeds that required for offset by 60%. Obtaining TLC in the experimental group, in contrast to the control group, evenly during the semester. The number of students performing tasks for independent work on the eve of the final certification for the discipline in the experimental group is much lower than in the control group.

The control system becomes more open and transparent, which is confirmed by the activity of students in the work with the website. This contributes to the formation of students' skills in building an individual educational route, planning the study time.

Summing up our practice of using SRAS, we would like to draw attention to five important points that we see as fundamental. First, instead of traditional scores, the system of temporary labor costs (TLC) is applied. Secondly, the system should be cumulative, and if the student goes on academic leave, his TLC is retained (they can be valid for 3 years). Third - the use of a weight factor by the teacher, which allows you to influence the study of discipline and shows the students a sample (peer review). The fourth is the application of the website, which is regularly (once a week) updated and is an open educational resource. The fifth is the use of mutual learning, not only for the mutual verification of works, the delivery of an offset in an interactive form, but also in the application of interactive methods of associative dialogue (collective mutual learning) in practical exercises.

The didactics of the higher technical school undergoes transformation, which is noted by many authors [11] and the application of SRAS is an important tool in the able hands of high school teachers. Any innovation has its pluses, advantages, and its disadvantages, risks in its implementation.

## References


1. Linnik E.V.: Metodicheskie rekomendatsii po primeneniyu ball'no-reitingovoi sistemy otsenki znanii studentov vysshikh uchebnykh zavedenii v sootvetstvii s FGOS v ramkakh sistemy ECTS: metodicheskoe posobie (Methodological recommendations on the application of the grading system for assessing the knowledge of students of higher educational institutions in accordance with the GEF within the framework of the ECTS system); "Evraziiskii otkrytyi in-t", 107 p. Azovskii fil. Azovskii filial EAOI, Azov (2013)
2. Kasyanik, P.M., Gulk, E.B., Olennikova, M.V., Zakharov, K.P., Kruglikov, V.N.: Educational process at the technical university through the eyes of its participants (2017). https://doi.org/10.1007/978-3-319-50337-0_36
3. Solodyannikov, V.A.: Ball'no-reitingovye tekhnologii v otsenke deyatel'nosti uchastnikov pedagogicheskogo protsessa (Score-rating technologies in assessing the activities of participants in the pedagogical process); S.-Peterb. gos. un-t servisa i ekonomiki, 118 p. Izd-vo SPbGUSE, Sankt-Peterburg (2010)
4. Otsenivanie obrazovatel'nykh dostizhenii studentov v ramkakh ball'no-reitingovoi sistemy v FGBOU VPO "TGTU" (Evaluation of educational achievements of students in the score-rating system at the TSTU). In: Rakitina, E.A., Mozgova, G.V. (ed.) Metodicheskie ukazaniya, Tambov gos. tekhn. un-t. TGTU, Tambov (2014)
5. Andriyanova T.V.: O realizatsii ball'no-reitingovoi sistemy na napravlenii podgotovki "Sotsiologiya": iz opyta raboty (On the implementation of the score-rating system in the undergraduate program "Sociology"): uchebnoe elektronnoe posobie, FGBOU VPO "Kursky gos. un-t". KGU, Kursk (2015)
6. Karamzina A.G.: Ball'no-reitingovaya sistema po distsipline (Score-rating system on discipline). UGATU, Ufa (2014)
7. Ball'no-reitingovaya sistema otsenki uspevaemosti studentov dlya realizatsii mnogourovnevykh obrazovatel'nykh programm VPO pri kompetentnostnom podkhode (Score-rating system for assessing the progress of students for the implementation of multi-level educational programs HPE with a competent approach): metodicheskie rekomendatsii, FGBOU VPO, 66 p. AGRUS, Stavropol' (2011)

8. Andreeva, T.Y. (ed.): Ball'no-reitingovaya sistema otsenki uchebnykh dostizhenii studentov: metodicheskoe obespechenie protsessa obucheniya (Score-rating system for assessing students' academic achievements: methodological support of the learning process), 77 p. Ural federal un-t im. pervogo Prezidenta Rossii B.N. El'tsina. Izd-vo Ural'skogo universiteta, Ekaterinburg (2013)
9. Kudinov, V.A.: Ball'no-reitingovaya sistema otsenki kachestva osvoeniya osnovnoi obrazovatel'noi programmy vysshego obrazovaniya (Score-rating system for assessing the quality of mastering the basic educational program of higher education): uchebnoe elektronnoe posobie, Kursk gos. un-t. KGU, Kursk (2014)
10. Makarova, N.S.: Transformatsiya didaktiki vysshei shkoly (Transformation of didactics of higher education): uchebnoe posobie, 180 p. izd-vo "Flinta", Moscow (2012)
11. Domarenko, E.V., Dombrovskaya, A.Y.: Realizatsiya ball'no-reitingovoi sistemy otsenki uspevaemosti studentov v rossiiskikh vuzakh: sostoyanie, problemy, perspektivy (Realization of a point-rating system for assessing the progress of students in Russian universities: the state, problems, prospects), Consept., № 11, November 2013. http://e-koncept.ru/2013/13225.htm

# Knowledge Management and Learning in Urban Revitalization Processes of Selected Non-profit Cultural Organizations in Slovakia

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**Abstract.** The aim of this paper is to present selected revitalization processes of inadequately used city buildings reflecting the implementation of lessons learned and effective knowledge management tools. We focus on the leaders of non-profit organizations who together with their teams have participated in successful conversions of historical buildings to alive cultural and community centers. Our research, covering a period of the years 2013–2016, has primarily concentrated on defining, delivering and exploiting tacit and explicit knowledge in certain revitalizing and operating stages of the studied venues in three Slovak cities – Bratislava, Žilina and Košice. On the basis of Nonaka-Takeuchi SECI model, a set of case studies and interviews as well as monitoring stakeholders' opinions and observing more than 200 events, the authors designed a tailored knowledge management model for non-profit organizations. The model has an ambition to serve as a framework to present best practices and to assist in managing urban revitalizing and sustainable approaches in the field of non-profit organizations. The crucial elements of such effort are creative and innovative actors with interdisciplinary thinking, who emphasize responsible and transparent organizational behavior and who, therefore, gain a necessary stakeholders' support. Outputs from our research have led us to generalizing and designing a knowledge management model that allows us to recommend it as an effective and inspiring learning tool for other non-profit organizations and useful material for students of management.

**Keywords:** Knowledge management · Learning · Urban revitalization
Innovation and creativity · Non-profit cultural organizations

## 1 Introduction

### 1.1 Knowledge Society

In recent decades, knowledge together with creativity is considered to be the decisive power leading to progress, competitiveness and higher quality of life. The Knowledge Era represents permanent and turbulent changes in economy, society, technologies and communication, connecting different areas, fields and disciplines. Currently, existing


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organizations and their leaders have to consider transformation processes in order to create innovative approaches and to remain competitive and sustainable.

Human creative activity has enabled the modification and improvement in living and working conditions and resulted in constant ability to perceive and react to changing conditions. Through history, gained knowledge, experience and skills have been shared, stored, learned, reused, refined and combined, depending on existing circumstances and available tools. Current transformation of "industrial cities" to so called "creative and smart cities" is connected with forming of a new society bringing such evident characteristics as urban population growth, cultural diversity, higher accessibility of services and relaxation, labor and educational opportunities. However, at the same time, it is necessary to consider other factors related to traffic, pollution, crime, inaccessible accommodation, unused buildings or abandoned neighborhoods. To solve urban development and revitalization processes it is vital to form creative and innovative approaches offered by non-profit organizations, representing interests of broader communities, and including collaboration of businesses and government representatives.

Our paper focuses on the analysis of knowledge management tools and learning models used in revitalization urban processes by selected non-profit organizations in Slovakia. The observed actors of the studied objects are founders and leaders of non-profit organizations, who together with their teams, developed and realized the conversion of inadequately and inefficiently used urban facilities to creative cultural centers.

The motivation for this study is to demonstrate how a creative and innovative approach enables overcoming barriers and obstacles coming from traditional ways related to attempts of transforming historical urban buildings. Our intention is to demonstrate how appropriate learning together with information sharing, knowledge management, effective communication and "bottom-up" activities result into successful and live facilities for various target groups.

The created model of knowledge management, including the SECI model, can be exploited for describing the advantages and disadvantages of the creative and innovative approach used in revitalization processes of urban culture by selected nonprofit organizations. It emphasizes the need of special attention to particular stages of knowledge conversion in order to achieve the desired goal: the efficient and effective knowledge management and communication among the team leaders, their teams and stakeholders. In other words, the purpose is to show how to learn from existing "good examples" and how to coordinate activities of non-profit organizations cooperating with government, businesses, media, target groups and volunteers.

Our goal is to present a model of knowledge management and learning for sustainable running of a non-profit organization focusing on urban revitalization processes maximizing advantages of innovative, creative and collaborative approach.

### 1.2 Transforming Role of Non-profit Organizations in Knowledge Society

Drucker states [1] that numerous American non-profit organizations have become the leaders of strategic management focused on motivation, effectivity and productivity with the policies inspiring even businesses. What was obvious practice in the USA in the middle of the 1990s in this sector, starts to get visible recently in the Central Europe, namely in Poland, Hungary, the Czech and Slovak Republic. Growing activities of the civic society with the irreplaceable role of the non-profit organizations is presented by gradual modification in which the so-called "third sector of the society" has become a significant and respected pillar, actively participating in transformation of social processes.

In the recent decades, non-profit organizations have become an integral part of a civic and democratic society and their main role is public service and assistance. However, their position, relevance and participation vary in different countries and regions. Since the end of the previous century, when the sector was legislatively defined, the increasing number of non-profit organizations in Slovakia proves a correct direction and reinforces reliability, transparency, and ethical and moral values.

Svidroňová [2] points to the fact the economic advantages for a state emerging from providing needed services for the public are evident and besides social and health assistance they include areas of education, culture, sports and environment. In addition to that she emphasizes the importance of the sustainability of non-profit organizations in order to maintain the required capacity while accomplishing their mission in long-time perspective. Moreover, in a position of "advocates" non-profit organizations help to protect democracy, human rights, annotate laws, and are able to guarantee higher quality, effectiveness, transparency, justice and lower expenses of their services.

## 2 Creative Society and Knowledge Era

There have been several significant milestones in the history of humankind. Within the development of our society we have gone from the Prehistoric Age, the Antiquity, through the Middle Ages up to the Modern Period, including its agricultural character to be replaced with a massive industrialization and following digitalization. In every single stage of the development, our ancestors were able to observe, learn, improve and cultivate their living standard. Human knowledge, experience together with innovative and creative potential have constantly contributed to the progress and higher life quality and today they have gained the status of a crucial/decisive economic power and source [3].

### 2.1 Knowledge Management

Either knowledge or knowledge management is not easy to unambiguously define. Numerous attempts agree on a "multidisciplinary paradigm", based on mapping processes with using knowledge database, including human mind and application of technologies. Appropriate methods of creating, utilizing, preserving, and disseminating knowledge enable to maintain desired organizational performance and contributes to increasing quality and improving competitive advantage. Moreover, Bureš [4] confirms a unique value and character of knowledge as they possess such attributes which are absent in other resources.

Our knowledge management model in addition to other elements includes also the SECI model as each of its stages, Socialization, Externalization, Combination and

Internalization help to share, transfer, combine and implement valuable experience and skills and thus reuse and refine them in order to create a competitive advantage [5]. This spiral model was modified for the purposes of our research and required a careful selection of the procedures and tools which reflect requirements of our observed non-profit organizations in their efforts, see Fig. 1.

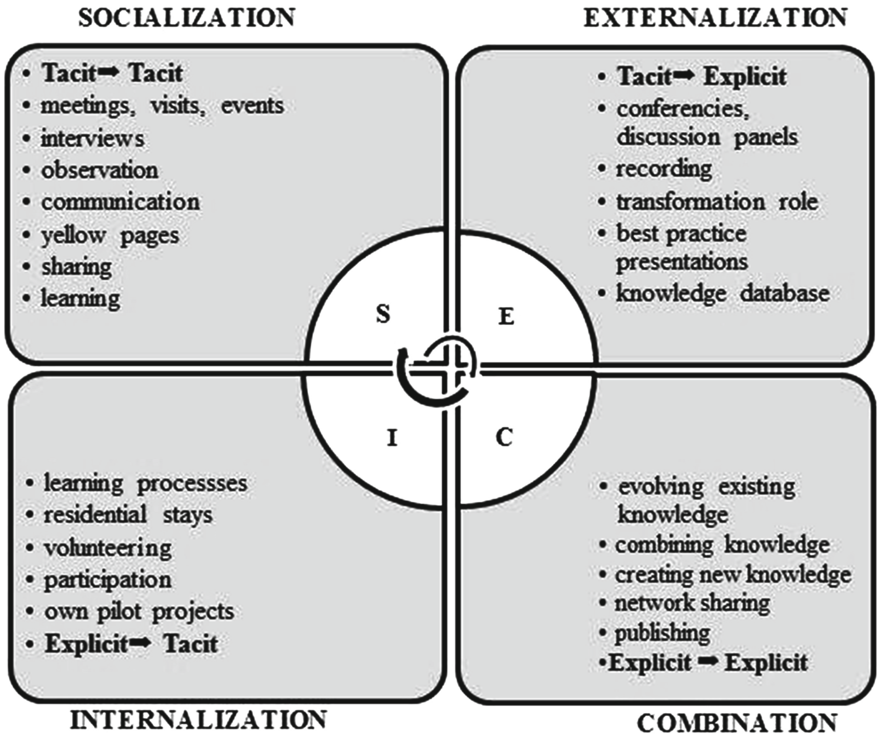


**Fig. 1.** Tailored SECI model in a framework of revitalizing urban processes in selected non-profit organizations

## 2.2 Creative Class and Creative Cities

Florida and Hawkins were among the first authors who pointed to the influence and contribution of creative economy and defined the term "creative class", as talented, unconventional and innovative people. These creative and interdisciplinary thinking individuals cross the borders of sciences, arts, architecture and design, theatre, fashion, music, crafts, media and information technologies. Numerous studies prove that the contribution of creative industries keeps increasing and it is becoming one of the key industries providing the market with new job positions.

Cities have been the centers of cultural life, trading, and education for centuries. Currently most of the population, up to three billion, lives in cities which have become multifunction locations determining social, civic and business life, and by 2030 is expected to increase up to five billion. Current forming processes of a society are linked with a transformation of industrial cities to creative cities, where significant accelerating power comes from the non-profit sector. Thanks to their initiatives and active enthusiasm, their representatives are able to participate in numerous civic activities and projects and thus guarantee sustainability, transparency, quality and accessibility for more target groups, which contributes to the revitalization of urban neighborhoods [6].

## 2.3 Case Studies

A part of our research was focused on case studies, the selection of which was carefully carried out and specific conditions were taken into consideration. Our six case studies monitor urban reconstructions in three main Slovak regions and their capital cities under management of non-profit organizations. A large amount of information and demanding conversion processes required a complex and systematic approach in data selection, comparison and analyzing of observed phenomena. Only the integrated framework and unified criteria could lead to designing the intended knowledge management model as an effective learning tool.

See the location of the studied cases in the cities of Bratislava, Žilina and Košice that present successful stories of urban revitalization processes, and resulted in frequently visited, alive cultural centers (Fig. 1).

### 2.3.1 Selected Slovak Regions

The Bratislava Region represents the smallest area with Bratislava, the capital of Slovakia, and the largest city in the country. Such attributes as a strategic location, developed infrastructure, a seat of institutions, companies, science and education as well as qualified labor power contribute to prosperity, economic and social growth, the highest salaries and the lowest unemployment. Besides rich history, cultural life and


**Fig. 2.** Regions in Slovakia

tourism, significant progress in banking, insurance, trade, and services is obvious as well (Fig. 2).

The North part of Slovakia, with its seat in Žilina, presents an important traffic node of both road and railway transportation on the national and international level. The region continues its long-term tradition in machinery engineering with the recent connections to automotive, electronic, hi-tech, telecommunication, logistic and wood industries. The area is known for its unique nature, spa tradition and rich history.

The second largest and prosperous city Košice is the seat of the south-east part of Slovakia, located in several protected historical and natural territories. This attractive location is at the same time a dynamic area with highly developed industries, trade, services, science and research centers, as well as educational and cultural institutions.

The city of Košice had the honor to be the European Capital of Culture in 2013 and European City of Sport in 2016 (Table 1).

**Table 1.** Basic data related to the self-government regions in Slovakia

| | Selected objects | Regions – area, inhabitants | City |
|---|---|---|---|
| 1. | Cultural Center Dunaj | Bratislava, 2 053 km$^2$ | Bratislava |
| 2. | Old Market Hall | 633 288 inhabitants | Bratislava |
| 3. | Train Station Záriečie | Žilina, 6 808,4 km$^2$ | Žilina |
| 4. | Synagogue | 690 434 inhabitants | Žilina |
| 5. | IC Culture Train | Košice, 6 754,5 km$^2$ | Košice |
| 6. | Tabačka Kulturfabrik | 796 650 inhabitants | Košice |

Source: Authors according to http://www.civil.gov.sk

### 2.3.2 Selected Revitalized Urban Projects and Non-profit Organizations

Each studied project represents a specific and original history covering three significant regions in Slovakia and was observed upon certain common criteria, presented in the Table 2. Selected objects of our research possess both creative and innovative approaches emphasizing multifunctional and sustainable revitalization of inadequately used or abandoned city buildings. In Bratislava, it was a former department store Dunaj and the conversion of its 4$^{th}$ floor to the Cultural Club Dunaj and historical City Hall serving now as a multicultural urban center, including regular Saturdays' markets. Žilina, known for its alive independent cultural node, located in the Train Station Záriečie, very recently opened a reconstructed Peter Behrens's Synagogue, with the intention to become creative and open Kuntzhalle. A reconstructed center of alternative culture - IC Cultural Train, located in one of the suburbs in Košice, after three years took up the challenge of moving to the Košice city center and revitalizing old tobacco factory as the center of independent cultural territory - Tabačka Kulturfabrik.

**Table 2.** Comparison and summary of the studied categories of the research projects

| | Studied categories | Comparison and summary |
|---|---|---|
| 1. | Actors & activities | In all studied projects there are creative and innovative leaders possessing former experience in non-profit cultural sector. Together with the team members they share knowledge in organizing and managing reconstruction, financing, dramaturgy and communication |
| 2. | History & building revitalization | A common sign of all buildings is their originally different purpose and historical value. After the reconstruction and conversion they will serve as cultural community centers |
| 3. | Building scope | Within the research project there is a similarity in building conversion towards community cultural centers, independent culture, social events, markets, and creative industries as hubs, labs |
| 4. | Program scope | All objects possess multi-genre dramaturgy, regular markets, creative and innovative workshops, charity events, various services as shops, bars, café |
| 5. | Target group(s) | Broad age and interest spectrum, social categories, locals and visitors, representatives of all sectors |
| 6. | Team | Creative, innovative and interdisciplinary individuals educated professionals with experience and skills. They work in organizations with strong culture, vision, and use conceptual and system thinking, leading to effectiveness and sustainability |
| 7. | Project financing | Multi-sources financing focusing on sustainability and transparency |
| 8. | Stakeholders' reaction | Declared continual support, long-term interest, best practice status, awards for development, local and international network membership, effective communication, transparency and sustainability |

All mentioned revitalized projects in Table 2 have happened within a complex and conceptual framework implementing creative and innovative management of nonprofit organizations. Both the leaders and their teams were able to learn and share valuable knowledge and experience from their own former projects or from exploiting their Slovak or foreign peers' skills. Not only the reconstruction itself but also the entire operation of the venues, including program offers, communication and collaboration with stakeholders and financing, deserves to be identified as a "success story". These examples of outstanding urban conversions reflecting effective learning processes and knowledge management have caught the public and experts' attention and our skilled actors gained several Slovak and foreign awards.

After analyzing and comparing studied categories in the selected objects we were able to identify similar and different characteristics. The summarized outputs from the set of case studies led us to the conclusion that observed non-profit organizations indicate almost identical signs in the given categories. Their effort to transform dysfunctional buildings to vibrant cultural centers providing rich program and addressing several communities as the young, families, seniors, creative students and artists as well as local and tourists. Common procedures were visible also in the open communication with stakeholders and receiving the feedback, respecting the transparent methods of financing and focusing on sustainability.

## 2.4 Interviews with the Managers of Non-profit Organizations

A fundamental part of our research was a set of personal interviews, as a qualitative research method, with the leaders and managers of the observed non-profit organizations. The intention of using identical questions was to search for similarities and differences and thus to identify successful practice and tools in knowledge and experience sharing. The purpose of this method was to gain opinions of the creative actors from the non-profit organizations in three Slovak cities. However, besides effective learning models and working procedures of managing revitalization processes our interest was also focused on such indicators as internal and external factors, opportunities and barriers. Last but not least, we were looking for identifications of those creative and innovative elements which distinguish them from the others and contribute to obvious success.

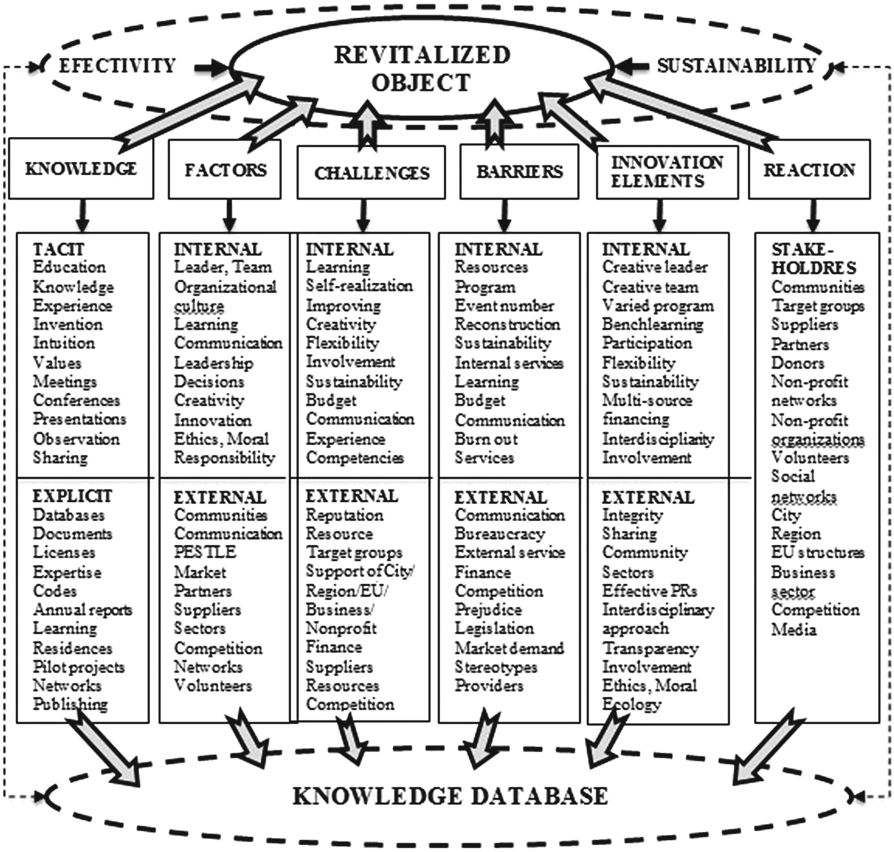


**Fig. 3.** Knowledge management model for revitalizing processes of urban cultural non-profit organizations

This paper tries to find the answers to the stated research tasks. Transformation of knowledge within particular stages of the SECI model is essential and requires appropriate categorizing and defining. This includes input of our selected team leaders and their team members but also other non-profit organizations, members of collaborative networks, supporters as well as involved stakeholders.

The outcomes were analyzed by using descriptions and comparisons of existing approaches and preferences of the research phenomena, including the internal and external environment of non-profit cultural organizations. Moreover, the SWOT analysis of innovative and creative approaches focusing on observed revitalization urban processes enabled us to highlight effective tools and methods in order to formulate criteria and conclusions (Fig. 3).

Our findings are summarized in a tailored model of knowledge management that can serve as a platform for shared knowledge, suitable learning models and a set of recommendations for appropriate coordination processes leading to effective, multicultural and sustainable urban cultural centers. Within the presented model, it is necessary to pay a constant and significant attention to the knowledge database serving as a basis of the human knowledge, procedures, data and solutions from different disciplines and fields. The contents of this effective tool has to be constantly gained, fulfilled, shared and created with the contribution of the motivated and creative knowledge workers.

The tailored knowledge management model presents research results of the revitalization processes of unused city buildings and their conversion to cultural centers and recommends appropriate knowledge management tools for either new or existing non-profit organizations willing to learn. Following the fact that knowledge management possesses a multidisciplinary character, we consider a need of a holistic and complex approach towards our research. The authors believe in the potential of creative and innovative approaches and bottom-up activities focused on the multifunctional exploitation of historical urban buildings and the strengthening of their “genius loci”.

## 3 Conclusion

The methodology of this paper was based on literature review related to the field of knowledge management, the SECI model, positioning of non-profit organizations in a society, the role of culture and transformation urban processes. The research included the selection of observed urban cultural centers managed by non-profit organizations which became analyzed in the detailed case studies. The following stage was focused on the identification and analysis of internal and external factors influencing operations of selected objects, including barriers, challenges, program structure, communication tools and innovative elements. Moreover, monitoring of perception, attitude and opinions of stakeholders became an integral part of a general evaluation to measure the progress and results of the revitalization urban processes.

The data collected in this research also included interviews with the selected team leaders and their team members, visits of sites, attendance of hundreds of organized events, observations of stakeholders’ reactions as well as media evaluation. All received data were analyzed, categorized and compared with a focus on defining elements of the innovative and creative approach used by non-profit cultural organizations focusing on revitalization urban processes. Finally, the data were projected into the tailored SECI model reflecting our needs and the knowledge management model mapping revitalizing processes of urban non-profit culture organizations.

Our goal was to design a model of knowledge management including learning possibilities as well as all factors having impact on creative and innovative ways in order to succeed in revitalizing urban processes. The gained outputs allow us to state that learning from "best practice" and defining the tailored tools of the SECI model is crucial and brings evident added value. However, recognizing and implementing the national and regional cultural differences is equally required. Otherwise, simple imitation of good examples with implementing certain universal principles does not bring desired results.

## References

1. Drucker, P.F.: Managing for the Future: the 1990s and Beyond. Plume, New York (1992). ISBN 0-452-26984-9
2. Svidroňová, M.: Sustainability strategy of non-government organizations in Slovakia. E+M Ekonomie a management **16**(3), 85 (2013)
3. Allison, E., Peters, L.: Historic preservation and the livable city. Wiley, Hoboken (2011). ISBN 978-0-470-38192-2
4. Bureš, V.: Conceptual perspective of knowledge management. E+M Econ. Manage. **12**(2), 84–96 (2009)
5. Hvorecký, J.: Knowledge and management. Jura Edition, Bratislava (2011)
6. Olejárová, M.: How creative approach and shared knowledge can help to revitalize the non-profit city project in Bratislava (2014). ISBN 9788089306202

# Data Visualization and Enhanced Learning in Engineering Education Through Oil Pollution Studies and Environmental Impact Assessment

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**Abstract.** Big Data and Data Analytics have in recent times become important areas of focus in academia, in business and in society. This paper utilises experiments involving data visualisation of oil pollution studies and their effects on environment for enhanced learning in engineering education. Tracking and analysis of images and the use of accessible applications for the analysis of acquired data revealed the level of impact of the different types of oil pollution on grass vegetation. In accounting for these changes the primary RGB colours and corresponding values are used. The use of spectral analysis applications available in spectroscopy and comparison of results would in future prove useful in assessing some aspects of these changes in relation to wavelength and colours changes. The results of these studies would contribute in no small measure to the determination of best cleaning strategies for oil spills.

**Keywords:** Data visualisation · Enhanced learning · Engineering education Oil pollution · Environment

## 1 Introduction

In engineering education and practice, there is a professional and ethical responsibility to assess and understand the problems facing the world today. Not only for our own development and understanding, but also to aid in the understanding in meaningful and intuitive ways of those affected. One such problem that has long existed in the public eye is that of environmental pollution and its impacts, more specifically that of oil pollution. When developing an understanding of these impacts it is important to realise that they can be analysed from more than one viewpoint, either professionally or from that of the public. As the world moves to becoming more dependent on digital media, it is vital that our methods of teaching and learning evolve to benefit and be supported by this transition. Local learning on environment has effect on awareness in learners [1–4]. This has potential to exert changes in individuals and society.


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Most notable and easily identifiable of these is the ecological impact. In the aftermath of any large scale accident or oil spill this is the impact that attracts the largest public outcry. Despite this however our means of analysis is focused around the understanding of the scientific community. While not inherently negative this creates a limitation when highlighting concerns or addressing the public.

The current research study, through experiments, sought to find a means of intuitive analysis for the ecological impacts that result from oil contamination of terrestrial plant life, as well as a means of tracking and understanding the changes undergone by the plant life post-contamination and how they can be used in the determination of cleaning strategies. The paper also reports on impact assessment of such level of pollution on environment through examining the effect of depth of penetration problem.

### 1.1 Background, Oil Pollution Studies and Environment

The goal of this project is to categorise the associated impacts of oil pollution and assess them in ways that are best supported by modern technology and its expansive outreach. A large part of this lies in making the assessments and their results more intuitively accessible to the public or a layperson. Often times it is a large public outcry that affects changes or highlights issues, as engineers and educators it is important that our means of teaching does not hamper the ability of those without academic or professional knowledge to learn and understand these issues. The determined impacts have been broken down into the following categories: social, political, economic, technological and ecological. This following extract from the report details the ecological effects as a result of a small scale oil spill.

## 2 Methodology and Approach

Three identical grass samples of dug from a sown lawn and potted in containers measuring approximately 350 mm × 210 mm were contaminated with approximately 50 ml each of the chosen oil types highlighted below:

- Kerosene
- Petrol
- Diesel

Macro Images were then taken at daily intervals when time permitted using an 24 macro lens on a 16 MP camera. The images were catalogued together for the chosen sample and are documented in the following pages under the section of the specific contaminant. Below each image is the dominant colour in that cell which has been determined through obtaining the colour value using the Adobe RGB Colour Space. The analyse for each sample has been carried out using 24 macro photographs of each sample taken across a period of 37 days following the contamination of the specified oil.

The effects of heavy oils such as kerosene and diesel on plant life are well established and upon experimentation they are expected to cause the most negative effect on the plant colour. Due to petrol's lighter atomic mass, it is expected to evaporate more quickly than the others and therefore cause less damage overall to the grass. As well as the colour changes, there are a number of other outcomes expected in that the size, shape, and texture of the grass leaf will also change across the testing period.

It is expected that eventually the colour variance of each sample, over a long enough period of time, will eventually reach the same final result. The difference will be however in the rate at which these changes occur, the negative effects of kerosene and diesel are to thought to peak before that of petrol.

## 3 Results and Discussion

This section documents the results gathered from the detailed experiment and analysis through the methods previously indicated. In each section there are a total of 24 macro images of the associated sample arranged in 3 rows of 8 images along with the specified day on which that image was taken. Below each image is the dominant colour in that cell that has been identified through the use of the aforementioned *Adobe RGB Colour Space* utilised in the *Adobe* editing software suite, in this case it has been done through *Adobe InDesign* although any other package would give identical results.

These colour cells have served the basis for the results to be analysed. By identifying the dominant colour in each image it has been possible to track and chart it changes throughout the specified timeline. Following each set of images for the sample is the corresponding graph. This has been plotted using the colour values obtained for that image in each the Red, Green, and Blue bands based on a scale of 0–255 parts per colour. This was plotted as a function of time through which the testing occurred. In this case it was over the course of 37 days, where Day 0 is the image taken before contamination occurred.

Following each graph there will be a discussion of the observed results in the form of both visual analysis, through the discussion of the changes from image to image, as well as analytical analysis as obtained from the colour cells and the plotted graph. Following this section is the table (Table 1) through which the graphs where derived from, it has been filled in with the red, green, and blue colour values for each image across each of the following 3 samples [6]:

- Kerosene
- Petrol
- Diesel

Kerosene is thin oil obtained from the fractional distillation of crude oil. It is unrefined petroleum; a highly refined form of kerosene is used in jet aircraft fuel. Kerosene is a mixture of hydrocarbons of the alkane series, consisting mainly of hydrocarbons with 11 or 12 carbon atoms. Boiling points of kerosene range from 160 °C/320 °F to 250 °C/480 °F. It is important to note that crude oil contains approximately 10–15% kerosene.

Petrol is mixture of hydrocarbons derived from petroleum, mainly used as a fuel for internal-combustion engines. It is colourless and highly volatile. Leaded petrol contains antiknock (a mixture of tetra ethyl lead and dibromoethane), which improves the combustion of petrol and the performance of a car engine. The lead from the exhaust fumes enters the atmosphere, mostly as simple lead compounds. There is strong evidence that it can act as a nerve poison on young children and cause mental impairment. This prompted a gradual switch to the use of unleaded petrol in the UK.

The changeover from leaded petrol gained momentum from 1989 owing to a change in the tax on petrol, making it cheaper to buy unleaded fuel. Unleaded petrol contains a different mixture of hydrocarbons from leaded petrol. Leaded petrol cannot be used in cars fitted with a catalytic converter. In the USA, petrol is called gasoline, and unleaded petrol has been used for many years.

Diesel oil also known as derv (diesel-engine road vehicle) is a lightweight fuel oil used in diesel engines. Like petrol, it is a petroleum product. RGB Values for the three primary colours red, green and blue (RGB) were analysed using the Adobe image analysis program. The RGB colour values for the grass sample obtained for the period of study is shown on Table 1.

**Table 1.** RGB Colour Values per Oil Type

| Oil Type | Kerosene | | | Petrol | | | Diesel | | |
|---|---|---|---|---|---|---|---|---|---|
| Colour value (0–255) | Red | Green | Blue | Red | Green | Blue | Red | Green | Blue |
| Day 0 | 35 | 65 | 0 | 81 | 109 | 58 | 16 | 41 | 0 |
| Day 1 | 36 | 81 | 0 | 38 | 93 | 2 | 42 | 86 | 0 |
| Day 2 | 50 | 67 | 31 | 35 | 85 | 14 | 40 | 96 | 7 |
| Day 3 | 47 | 80 | 37 | 58 | 106 | 22 | 69 | 101 | 0 |
| Day 6 | 117 | 111 | 75 | 77 | 102 | 1 | 119 | 141 | 77 |
| Day 7 | 193 | 172 | 109 | 101 | 153 | 9 | 200 | 177 | 101 |
| Day 10 | 211 | 170 | 152 | 59 | 94 | 4 | 164 | 109 | 88 |
| Day 11 | 245 | 210 | 182 | 53 | 104 | 25 | 208 | 171 | 145 |
| Day 12 | 202 | 180 | 131 | 219 | 187 | 114 | 146 | 117 | 85 |
| Day 13 | 154 | 138 | 86 | 219 | 187 | 126 | 173 | 130 | 88 |
| Day 14 | 180 | 133 | 81 | 219 | 177 | 119 | 146 | 109 | 64 |
| Day 15 | 165 | 139 | 114 | 146 | 138 | 63 | 177 | 139 | 116 |
| Day 16 | 178 | 147 | 129 | 140 | 107 | 90 | 168 | 127 | 99 |
| Day 17 | 205 | 151 | 104 | 153 | 113 | 87 | 172 | 152 | 66 |
| Day 18 | 216 | 176 | 127 | 189 | 148 | 82 | 149 | 111 | 90 |
| Day 19 | 188 | 137 | 80 | 135 | 92 | 57 | 177 | 138 | 105 |
| Day 24 | 202 | 166 | 130 | 144 | 92 | 55 | 106 | 73 | 58 |
| Day 28 | 201 | 160 | 98 | 176 | 132 | 71 | 95 | 65 | 41 |
| Day 30 | 194 | 161 | 128 | 204 | 151 | 97 | 139 | 99 | 91 |
| Day 32 | 159 | 120 | 103 | 167 | 116 | 89 | 177 | 135 | 110 |
| Day 33 | 199 | 160 | 127 | 177 | 124 | 84 | 143 | 102 | 84 |
| Day 35 | 187 | 149 | 113 | 164 | 118 | 84 | 128 | 94 | 67 |
| Day 36 | 200 | 172 | 148 | 149 | 108 | 88 | 149 | 113 | 81 |
| Day 37 | 160 | 112 | 76 | 133 | 98 | 70 | 166 | 121 | 88 |

### 3.1 Kerosene Results Analysis and Discussion

Kerosene by virtue of its properties was deemed to be one of the more damaging oils to be used, with the initial assumption being that it would see the most negative results across the smallest time frame. From the images, the degradation of the grass leaves starts around Day 6, this is noted in both the immediate colour change from a dark rich green, to a much paler, almost brownish-green, as well as the change in size of the leaves. In the days immediately before this image there has been no discernible change in the quality of the leaves themselves, the size and shape has been maintained throughout until this initial degradation on Day 6, where the leaves have first started to wither and die. This degradation continues on throughout the following images where the obvious drying out and withering of the leaves has occurred. This is noted both in their size and shape, as well as the colour as it continues to fade out of the green spectrum.

This continues to develop until *Day 14 (see* Fig. 1*)* or so where it can be seen that afterwards, there is no discernible difference in the leaf colour throughout the rest of the testing period. Following on from this point the colour variation is less extreme and follows a similar trend of more muted browns with slight yellow tones. The low quality of the leaf is simply maintained from that point onwards until the end of the testing period. It could be said that from about *Day 15* or *Day 16* onwards, is where the grass in that sample has died and will exhibit no further growth.

These observations are further evident in the associated graph, where between *Day 3* and *Day 6*, there is an immediate spike in the colour variation as the leaves begin to wither. This variation continues over the next 5 days until *Day 11* where the graph peaks indicating that this colour variation is towards the lighter end of the spectrum and shows one of the paler colours obtained from the analysis. Immediately following this peak there is a decline on *Day 12* as indicated by the darker colour the leaves start to exhibit. As previously visually observed, there is little colour variation beyond this point as around *Day 14*, the colour moves back towards the lighter end of the spectrum and begins to balance out, exhibiting little or no change as the testing period continues. This as previously discussed is the observable moment at which the leaves have died and will exhibit no further growth throughout the rest of the testing period.

### 3.2 Petrol Results Analysis and Discussion

Petrol is a much lighter oil than the other samples used and is expected to evaporate faster therefore minimising the negative effects on the grass sample. The initial degradation occurs much later in this sample, in fact this is the sample with the longest timeframe in which there is little to no variance in the observed colour. The variance here begins subtlety throughout the first 2 weeks but doesn't shift until *Day 12*, where the colour moves from the continuing rich, dark green tones to a much paler yellow tone. This change continues over the next few days until *Day 15* and *Day 16* where the colour becomes much darker as it moves towards shades of brown and the decline of the leaves health becomes more evident.

From *Day 16* onwards, the degradation is seemingly maintained as there is little to no colour variance occurring between images. The quality of the leaf can be seen in the

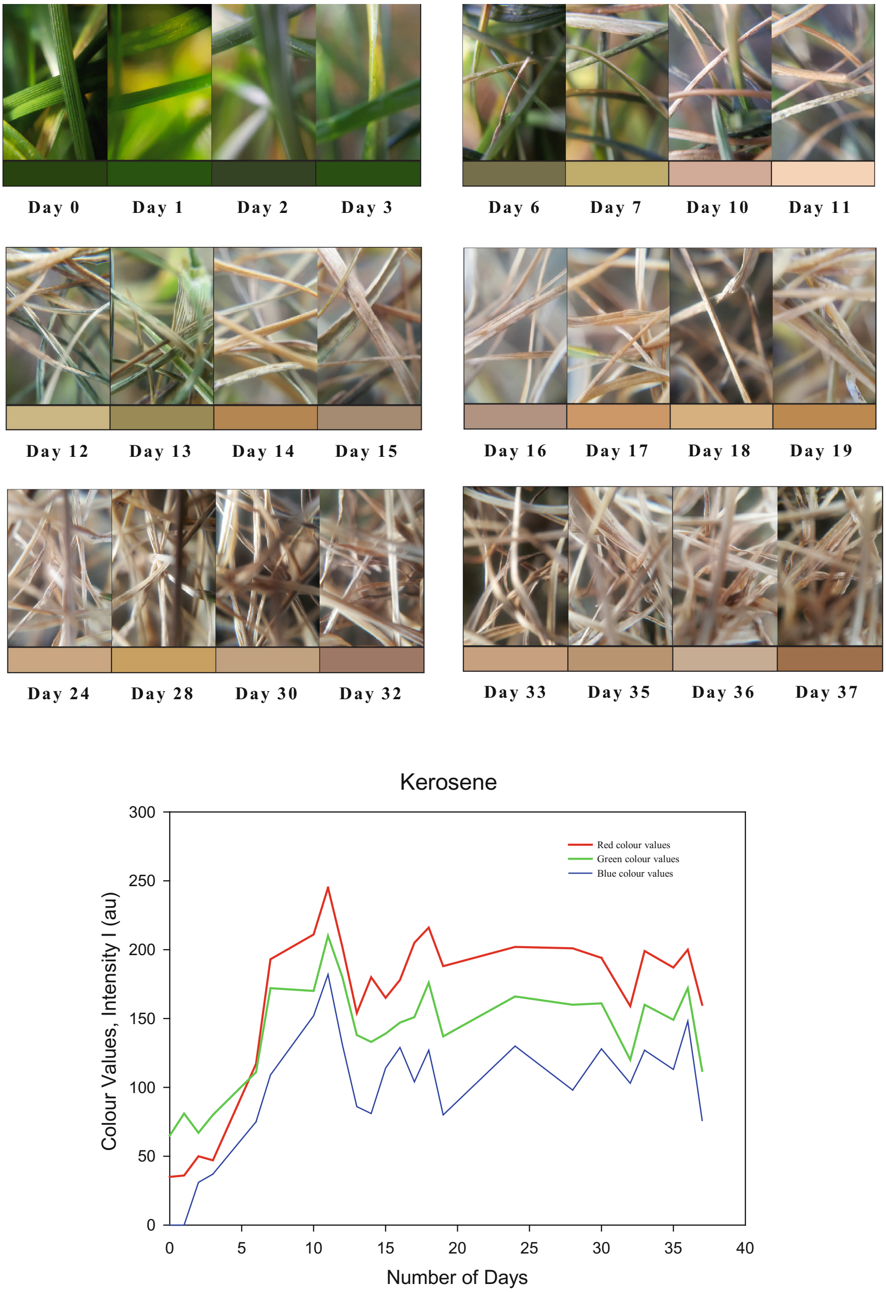



**Fig. 1.** Images of grass growth on soil contaminated with kerosene oil (top) and RGB colour values plotted as a function of time after contamination (bottom)

following week however, as from *Day 24* onwards, the leaves have begun to wither and die. From this point onwards there is little to no shift in colour or leaf quality meaning at this point it could be observed that the leaves have begun to die and will exhibit no further growth.

The graph (Fig. 2) indicates similar findings in that for the initial week there is no discernible variation in the leaf colour. Until that of *Day 12*, where there is an immediate shift from the darker, richer colours to the lighter end of the spectrum, indicating that the effects of the oil have only just begun. This variation towards the lighter end of the spectrum continues through the following days as little shift occurs in the colour. This paler colour is maintained until the immediate drop off occurring on *Day 15*. As previously discussed above, from this point onwards the leaves start to exhibit much more negative changes as the colour shifts lower on the spectrum again to that of more reddish tones away from the previous greener colours. As indicated on the graph, this colour variance is maintained throughout the rest of the testing period as the leaves begin to wither and die. This signifies that while the effects took longer to notice, the observable time in which the grass was undergoing a variance in colour, was a lot more abrupt than the other samples.

### 3.3 Diesel Results Analysis and Discussion

Diesel was believed to exhibit some of the harsher changes that would occur between samples. It was expected that the changes in this sample would be over a much shorter timeframe and the colour variance and degradation of the leaves exhibited would be much more severe than that of petrol. Just as previously observed with kerosene, the initial variation in the colour occurs on *Day 6* after the steady maintenance of the colour over the previous days. This variation is slight at first as it moves from the initial dark green towards a much paler shade of green and then on *Day 7* it moves closed to a yellow tone. This loss of green tones continues throughout the next few days where it becomes obvious that on *Day 11* that the leaves have already begun to wither and lose their colour. This is evident on *Day 12* where the colour has become a much more muted brown tone which continues developing throughout the remainder of the testing process.

Over the course of the week immediately following *Day 12*, there is little to no change in the colour variation until that of *Day 24*, where the tone drops to a much darker brown as the leaves maintain their withered state. There is a somewhat noticeable change in the size of the leaves between *Day 19* and *Day 24* as they continue to wither until their lowest point on *Day 24*. At this point it could be said that the death of the leaves has occurred and they will exhibit no further growth or changes. These darker tones are then maintained throughout the rest of the testing process showing no discernible changes over this period.

As shown in the graph the colours remain dark and rich through the initial days and then on *Day 6* they immediately shift towards the lighter end of the spectrum where they remain over the next few days (see Fig. 3). This is evident in the much lighter shades of green the samples exhibit over these days. As discussed above, the degradation continues on *Day 12*, where the colour shifts down again on the spectrum and is more or less maintained as slight and subtle variations occur throughout the remainder

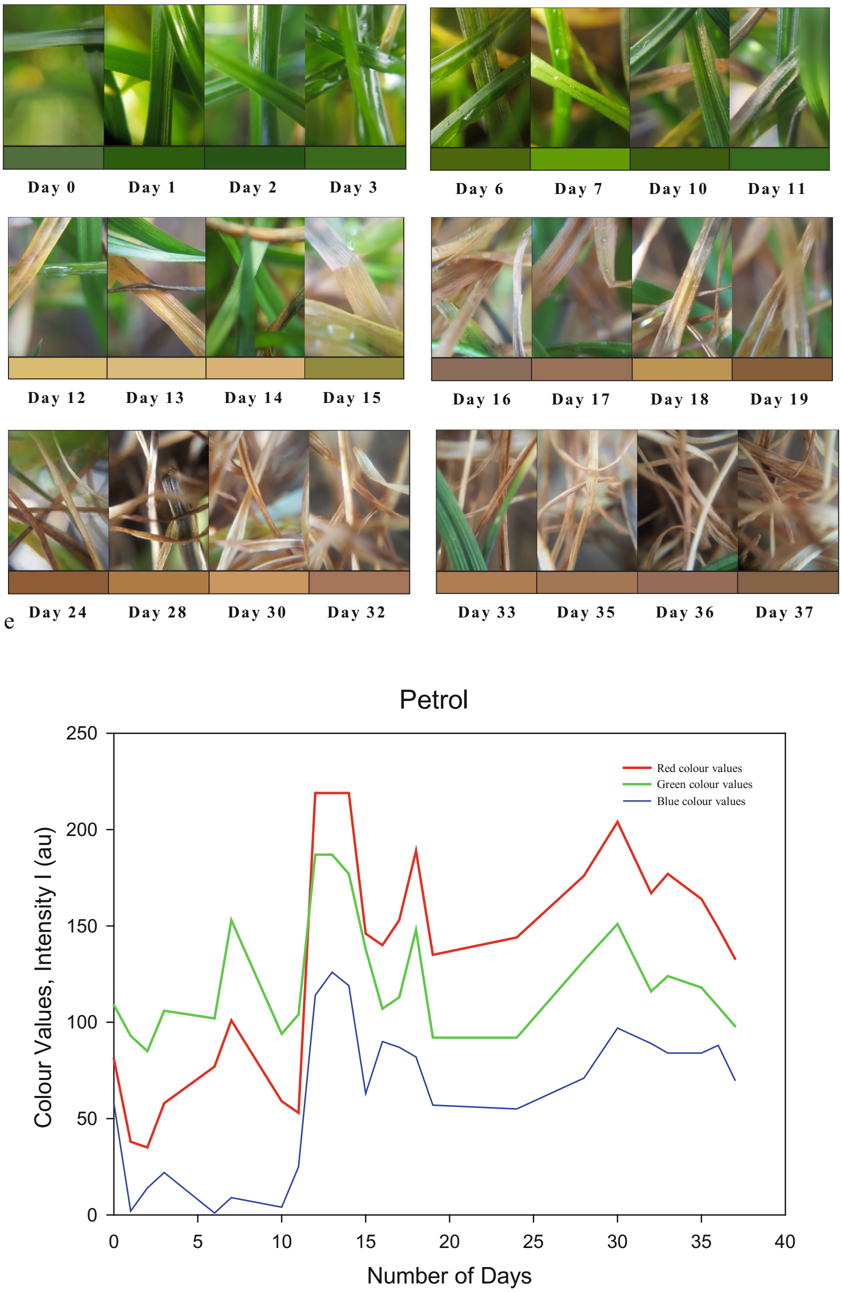
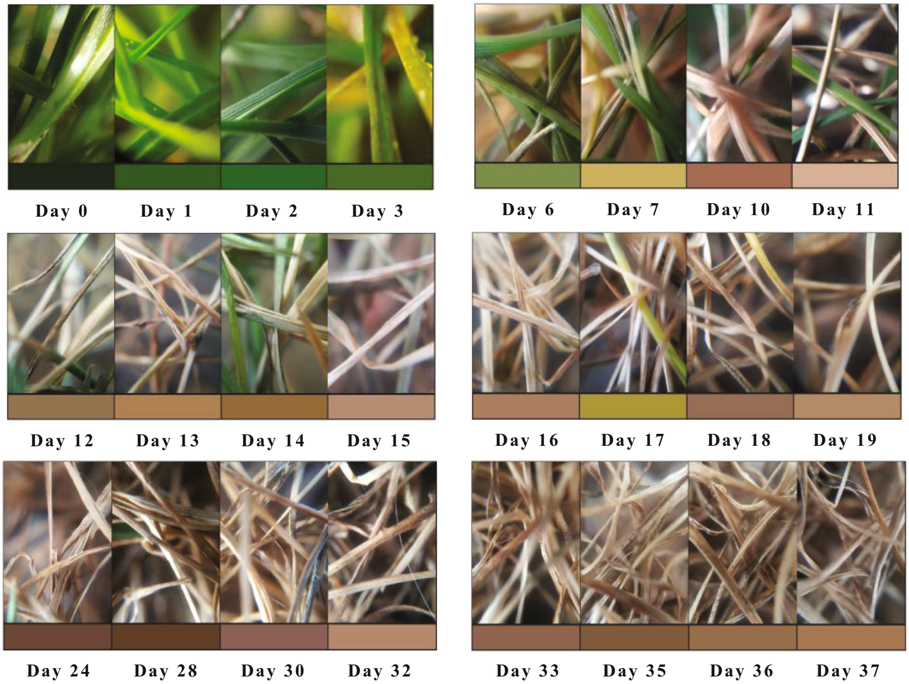



**Fig. 2.** Images of grass growth on soil contaminated with petrol oil (top) and RGB colour values plotted as a function of time after contamination (bottom)



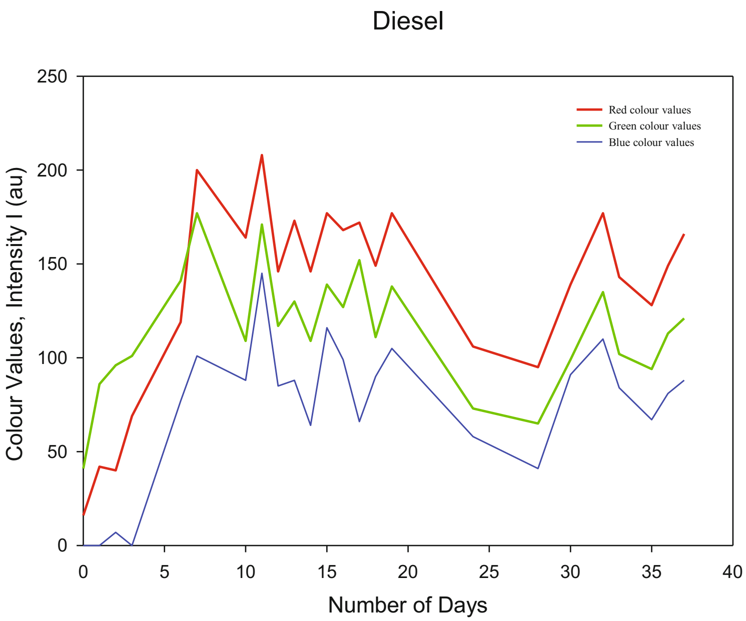




**Fig. 3.** Images of grass growth on soil contaminated with diesel oil (top) and RGB colour values plotted as a function of time after contamination (bottom)

of the testing period. The much richer, dark brown tones are evident here as on *Day 24* the colour shifts lower on the graph again towards the darker end of the spectrum. Where it once again slightly adjusts and is maintained until the conclusion of the testing period. The use of easily accessible applications for analysis and interpretation of these results has proved helpful in visualizing and understanding changes that occur in common vegetation.

## 4 Conclusion

Results of the current research seem to confirm some of the assumptions made at the beginning of the study. While the effects of oil on grass are well known and have previously been documented, these results stand to not only confirm them, but also to serve as a benchmark to which other samples could be compared to. Each of the samples were subjected to the same environmental conditions meaning the only variable was the type of oil used to contaminate that sample. This goes to show little variance from the anticipated results, thus confirming that the methods used for the process to be in accord with standard.

Environmental issues are complicated as most of them are open-ended. They oftentimes involve social, economic, cultural political and scientific factors, which are interwoven. The solution to these issues require a myriad of possibilities [5, 7–9] and a process which involves the understanding the practical implications of proposed solutions, evaluating scientific evidence and assessing proposals which could be loaded with environmental and economic consequences. Research into big data and visualization improves understanding and hence helps and should contribute to the making of informed decisions.

Were these experiments to be repeated on a larger scale, it is hoped that the results obtained would not only match up with the expected results, but that they also could serve as a basic guide, as a means of visually assessing the type of contaminant and severity of contaminated plant life across a number of different industries and sectors; including civil, urban, agricultural, marine, as well as learning tools in schools or colleges. As these environments and/or workplace may not necessarily be made up of only specialists in this field, it is important that the original aim is adhered to in order to best serve as a teaching tool. The measuring and tracking of the colour variance between each sample was chosen as it was the most obvious and easily monitored change that occurred in the samples. This meant that the obtained results could potentially serve as a simple, intuitive indicator of the changes that has taken place across a specified timeline of contaminated plant life that could be better understood by those outside of the engineering profession. We conclude that data visualization of diverse easily observable phenomena such as oil pollution has the potential to enhance learning in engineering education, aid assessment process and provide deeper understanding of effect of such pollution on environment.

## References


1. Fisman, L.: The effects of local learning on environmental awareness in children: an empirical investigation. J. Environ. Educ. **36**(3), 39–50 (2005)
2. Grasha, A., Yangarber-Hicks, N.: Integrating teaching styles and learning styles with instructional technology. Coll. Teach. **48**(1), 2–10 (2000)
3. Howe, R.W., Disinger, J.F.: Teaching Environmental Education Using Out-of-School Settings and Mass Media. ERIC/SMEAC Environmental Education Digest No. 1. ERIC Clearinghouse for Science Mathematics and Environmental Education, Columbus OH (1988)
4. Kunkle, D.R.: Lehigh Gap History and Restoration. Wildlife Information Center, Slatington (2004)
5. Environmental Literacy Council: Resources for Environmental Literacy. NSTA Press, Arlington (2007)
6. Collins Dictionary of Science. HarperCollins Publishers, Glasgow (2003)
7. Onime, C., Uhomoibhi, J.: Cost effective visualization of research data for cognitive development using mobile augmented reality. In: AVI 2016, International Conference Workshop: Road Mapping Infrastructures for Advanced Visual Interfaces Supporting Big Data Applications in Virtual Research Environments 7–10 June 2016, Bari, Italy (2016)
8. Harrison, J., Uhomoibhi, J.: Engineering study of tidal stream renewable energy generation and visualization: issues of process modelling and implementation. In: AVI 2016, International Conference Workshop: Road Mapping Infrastructures for Advanced Visual Interfaces Supporting Big Data Applications in Virtual Research Environments, 7–10 June 2016, Bari, Italy (2016)
9. Onime, C., Uhomoibhi, J.: Smart technologies and applications for visualization in higher science and Engineering education: issues of knowledge integration and virtual experimentation. In: IEEE EDUCON 2017, IEEE Global Engineering Education International Conference, 26–28 April 2017, Athens, Greece (2017)

# Universities Should also Learn

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**Abstract.** The political changes after the fall of Communist command found their institutions of tertiary education unprepared. Often, their "spirit of obedience" still survives and have various consequences including their mental disability to accept innovative teaching methods including e-learning, massive open online courses, etc. As a case, our paper analyzes the situation at Slovak universities from the point of view of Knowledge Management. We propose Organizational Learning as a method expecting the universities to become "living bodies" using the trial and error methods in order to learn from their own experience as well as from experience of sister institutions around the World. As we believe, it is the only way leading to their development and prosperity. We present four roles of universities that could serve as potential transition models and a framework that supports building an "atmosphere of learning".

**Keywords:** Quality of tertiary education · Transition of universities
University roles · Diversification of universities · Academic culture
Knowledge Management

## 1 Introduction

The political changes after the fall of Communist command and splitting of Czechoslovakia found the Slovak system of tertiary education unprepared. The oldest university is less than one hundred years old and the most of higher education institutions were established subsequently during the dictatorial regimes in the 20$^{th}$ century. In the moment of the political change (in 1989), their understanding of academic freedom and university autonomy was negligible. Their "spirit of obedience" still survives and have various consequences including mental disability to accept innovative teaching methods including e-learning, massive open online courses (MOOC), etc.

To a certain degree, the situation repeats itself in all post-Communist countries. Our paper analyzes the situation in Slovakia from the point of view of Knowledge Management. First, we identify several university models and show that Slovak university are following just one of them – the most conservative one. We study why just this one (a direct descendant of central planning administration) still persists. We analyze the preconditions for legislation changes which might lead to their wider diversification via appropriate motivation. The motivation tools are described in detail.


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Our analysis starts with describing extreme cases of regress. We indicate that the evaluation processes applied by Slovak Accreditation Commission – initially accepted in good intent – in a stepwise manner had changed to a tool deforming university life. Its focus is extremely narrow. Its methods are very bureaucratic with a strong orientation to research understood predominantly in a formal scientometric way. Its evaluation criteria disregard quality of teaching and social role of universities.

In looking for a diversified university system, we study four roles of universities identified by Boyer [1]:

- *Discovery,* i.e. original research;
- *Integration,* i.e. the synthesis of information across discipline(s) and/or time;
- *Application,* i.e. the engagement involving the rigor and application of expertise;
- *Teaching and Learning,* i.e. the systematic study of educational processes and their stepwise development based on the findings.

In the end of our analysis, we present a framework that has to be implemented in order to achieve a "culture of learning". The framework consists of a series of (partially independent) activities. Each of them will stress a certain conduct enhancing a specific university trait. To follow it will require a university management's decision combined with its desire to become different. Such approach might affect the currently dominating "culture of obedience" and, hopefully, invite universities to replace it by building up their own profiles.

The key to transformation we propose concentrates on the necessary changes in the Slovak legislation. We are well aware that the formation of a diverse academic environment will last long. At the same time, provided the universities will become active and the legislation change will support their efforts, the first results may appear quite soon. In any case, it is obvious that past twenty seven years have been unexploited due to almost a zero desire for any real and productive change.

## 2 Transition of Tertiary Education: Slovakia as a Case Study

The Slovak higher education system is rather juvenile. The oldest university (Comenius University in Bratislava) will celebrate its 100th birthday in 2019. The substantial proportion of public universities was established between 1939 and 1989 by autocratic governments during totalitarian regimes. After the Velvet revolution, their dominant mindset remained in the mode "to obey and to serve" rather than "to comprehend the concepts of academic freedom and apply them to the life of academia".

The main legacy of this unfortunate development is a boring, uneventful, and monotonous academic life. Recently, it has got under the mixed pressure of two substantive powers – the above mentioned tradition and the domestic Accreditation Commission (AC). The AC was established in early 1990s and its initial aim was quite positive: to facilitate research activities and move universities closer to the modern university model represented by the Humboldtian one [2]. This choice was logical because it used to be the only model known during the interwar Czechoslovak Republic – the short and exclusive period of democratic rule in the Slovak universities' history.

Nonetheless, almost no one (including the AC) have noticed that the higher education in modern developed countries have already followed other complex directions. The central of them has been the move from the traditional Humboldtian model to the Neoliberal model [3]. Thus, the AC has introduced the rules preferring research activities above any other one and measured it mostly by scientometrics. In this way it motivated the universities to increase their research (which is a positive trend) but demotivate them to excel in any other field including education (an evident blunder).

At the same time, the Slovak educational system is underfinanced, which limits its quick progress in gaining high-quality research outcomes. In addition to all above, many universities lack their extrinsic and intrinsic motivations to develop in other than this "prescribed" direction. As they are exclusively evaluated by the unified criteria stated within the continued "culture of obedience", they do not feel a necessity to work on a different one. As a result, there is no diversity.

The outcomes of 27 years of latest development are quite unfortunate [4–6]:

- The accreditation and evaluation processes are incompatible with the European standards defined by ENQA. As a result, the Slovak AC was expelled from ENQA in 2012.
- None of Slovak universities has ever appeared in 500 most prestigious World ranking yet.
- The university career is not attractive for young people; the average age of a professor is 62 years.
- The collaboration between universities and industry is negligible.
- The system is closed: the numbers of both foreign educators and students belong among the lowest in the EU.
- There persists inequality in access to higher education among social groups.
- Due to a low interest in improving teaching skills, modern methods of education (virtual classrooms, MOOC, collaborative learning, etc.) are rarely used. In addition, they do not play a role in staff promotion – even at Faculties of Education.
- Megalomaniac projects are preferred to a systematic development of research environments. For example, there have been 7 research parks in Slovakia compared to 1 in Austria, 2 in the Czech Republic, or 4 in Poland.
- Estimations guess that over 20% of high school graduates study abroad. About 50% of them do not plan to return to Slovakia.

Some of these negative outcomes are now evident and recognized by the Slovak universities, e.g. growing numbers of Slovak high-school graduates emigrating the country and entering universities abroad. They still apply "repelling" marketing policies especially by their low interest in modern educational methods. As data show, to the question "*What should change (in tertiary education) to make you study in Slovakia?*" 71% of Slovak students studying abroad responded "*Total function of the schools*" [7]. Their proportion is the third highest in the European Union after Luxemburg and Cyprus [8]. Unfortunately, the universities are not ready to acknowledge their share on these endings. Their needed changes should not only address the style of teaching, but for example the low ethical standards including frequent – proved but not penalized – cases of plagiarism and bribery. The situation repeats in many East European countries.

For example, Bratianu states on Romanian universities [9]: "*In most of our universities, mediocrity is dominant and values are rejected.*" He formulated this antagonism as a paradox [10]: "*Although a university is an organization based on learning processes, it is not necessary a learning organization*". To solve causes not just effects means changing the universities to learning organizations.

## 3 Three Challenges

The first Slovak university was establish almost one hundred years ago. Since the beginning of 20th century, the world universities has underwent substantial developments. It was their response to three main challenges of industrial and information era [11]:

1. **The move from "academically-oriented" to "mass-oriented" universities:** The restructuralization of post-war industry led to new professions requiring intensive knowledge and specific skills that cannot be achieved at high-schools. The transfer began in the USA and quickly spread to most developed countries. It did reach the post-communist countries only after the political breakdown in the 1990s and had to encounter the university tradition that still considers tertiary education as elitist despite the fact that their number grew significantly compared to the pre-revolution period.
2. **The rise of Knowledge Society:** As knowledge becomes recognized as a working power, it must become applicable, not only theoretical. Thus, some tertiary education institutions started oriented themselves to such mixtures. They developed into a new type of universities named the Universities of Applied Sciences, in our region better known by their German name Fachhochschule. Some traditional universities also offer professionally oriented study programs up to the level of PhD (included).
3. **Reducing the distance between the students and their expected future knowledge and needed skills:** New educational methods have emerged. Some of them reduce geographical distance (virtual classrooms, MOOCs, etc.), other introduce elements developing specific skills including social ones (group projects, open problem solutions, collaborative learning, etc.)

Each of these three challenges contradict the concept of "elitist education" – the prevailing approach to tertiary education in Slovakia. The conclusion is that we need a different tertiary educational system. To understand the challenges and ways to face them should be the content of their "learning". It does not mean that the Humboldtian model of university should be dismissed. It has its right to exist and develop [3]. The challenges only indicate that this model cannot remain the only one; the other ones have to be settled and concurrent.

The problem of inappropriateness of commonly accepted practices has been intensively studied in both Czech and Slovak Republic – see [3, 12–16]. Unfortunately, their results have not been applied in practice to the desired level. Their authors criticize the existing state from various directions. However, they share the idea that the traditional Humboldtian university model is not the only one and cannot fit to all contemporary requirements. Despite their different accents, they all call for growing diversity in tertiary education.

The recent development has been rather opposite. Whilst Learning Organizations [17] are guided with the principle: "*If we will not learn, we will extinct*", the Slovak universities share the conservative attitude: "*If it works, do not change it*". There are various reasons rooted in the autocratic tradition but one has been dominating – an intensive preference to more and more formal criteria enforced by the Accreditation Commission. All Slovak tertiary institutions must overcome their periodical evaluation once per six years. Due to the mechanically applied numerical criteria, the universities have learned to simulate their research activities by organizing pro forma conferences and by publishing papers and books of the quality expected as the "bottom edge". They behave like Learning Organizations but resemble lazy students who just balance on the edge between passing and failing grade.

Their incorrect behavior is a result of another methodological error in the Accreditation Commission's evaluation procedures. The scientometric criteria applied by the Accreditation Commission are to a certain degree applicable to the model of research (i.e. Humboldtian) university. Also, the Neoliberal model prefers quantity above quality, metrics above the content, and instruments above the goals. But one can hardly define the same criteria to medicine, mathematics, and philosophy because their research methods and valued results significantly differ. They are without any doubts applicable to many contemporary universities oriented to mass education preparing students to their role in the Knowledge Society. However, their capability to enhance a long-term growth of academic standards can be questioned.

Such an approach violates another principle of Learning Organizations [17] – the accent on their autonomous ability to learn and adapt to their ever-changing environment. Thus, one has to analyze whether the environment the universities live in creates conditions for their further development.

## 4 Creativity in Academia

The elitist model trains "*elite students to become the future elite of society*". The mass education model prepares "*apt students to properly fulfil their roles in their future positions requiring high-level qualifications*". To reflect the difference, the universities must start acting as learning organizations.

The new approach to university student's knowledge development must therefore reflect more than formal (explicit) knowledge. The universities must incorporate the educational strategies developing their students' tacit knowledge and social skills in order to guarantee the applicability of gained knowledge enhancing innovations and prosperity in professions not yet existing. Proposing a complete list of activities developing these skills in impossible but there exist guides to this field. For example, Hvorecky et al. show [18] that decision making and problem solving need more than a purely rational ("scientific") approach. They also present a list of the most frequent not-fully-rational activities – see Table 1.

**Table 1.** Not-fully-rational activities behind the SECI model

| Socialization | Externalization |
|---|---|
| Story-telling<br>Discussion<br>Opposing common opinions<br>Listening to other opinions<br>Showing example behavior<br>Teaching and training<br>Brain storming | Speaking and writing excellence<br>Capturing of the idea's core<br>Formalization<br>Introduction of a new notation<br>Posing "right" questions<br>Demonstrating skills |
| **Internalization** | **Combination** |
| Digesting a new piece of knowledge<br>Practicing a new activity<br>Implementing a problem solving method<br>Learning a new formal notation<br>Becoming involved in the topic<br>Understanding potential "usefulness" of knowledge | Lateral thinking<br>Creating analogies<br>Selection of the right data- and information-processing method<br>Identification of the new piece of knowledge |

Source: [18]

At the same time, the scientometric view to the university quality only includes rational criteria. Criteria reflecting the full variety of academic creativity with their relevant benchmarks must be developed. The educator's excellence must not be limited to their publication intensity. Table 1 shows that there are many activities which are integral part of education, service and research and should therefore become an integral part of academician's weaponry.

First, we have to underline the fact that the pressure on research at universities (in this today's form) only started in the end of 19th century. A wide gap now exists between the myth and the reality of academic life. In 19$^{th}$ century the European countries followed different models. For example, under Napoleons' government the concept of Grandes Écoles has developed in France. They can be presumed the predecessors of the Universities of Applied Sciences. The research university model does not developed quickly from the Humboldt's visionary paper [2] dated to 1809, the first research universities date to 1890's [19]. Regardless many new inventions and discoveries coming from research universities, their high-quality teaching has always been considered as their primary advantage.

Consequently, "pure" research is not the only way the university educators (and the institutions themselves) can demonstrate their quality. Boyer speaks about four key professional activities which he names "scholarships" [1]:

- **The scholarship of discovery** that includes original research that advances knowledge;
- **The scholarship of integration** that involves synthesis of information across disciplines, across topics within a discipline, or across time;
- **The scholarship of application** (engagement) that goes beyond the service duties of a faculty member to those within or outside the University and involves the rigor

and application of disciplinary expertise with results that can be shared with and/or evaluated by peers; and
- **The scholarship of teaching and learning** – the systematic study of teaching and learning processes.

Each type of these scholarships requires a relevant (and very different) type of creativity of educators. For example, despite the fact that the university studies offer the highest level of education, not all of their graduates must become the intellectual elite. On the other hand, the educators are supposed to be such. They will prove their quality by delivering every particular course in the best quality flexibly adopting its content to the composition of students they face. They must be capable of adopting its content in the manner comprehensible by the students, elaborating it in an appropriate format (lecture notes, collections of solved and unsolved problems, discussion topics, graphs, illustrations, tables, etc.) and delivering it in an attractive manner that will hold their students' attention and motivate them to learn. These capability requires not only their deep and intensive knowledge of the field but also their ability to transfer it to the format appropriate for the study cohort they face and modify it in accordance to their progress by applying the maximum subset of not-fully rational activities showed in Table 1. The importance in such holistic knowledge development is undisputable:

- **Discovery creativity** remains a key to new knowledge. Without being a birthplace for it, universities would not fulfil their role. In addition to its intensive performance, the ways of its enhancement must be studied [19].
- **Integration creativity** is a gate to critical thinking. It helps the students to formulate interdependencies between isolated facts and start comprehending their mutual relations. Today, many facts can easily be found on the Internet; their relationships rarely. Unless the teachers with highly developed integration skills will train them in finding and disclosing them, the students will be unprepared for distinguishing between relevant and less relevant facts. They will quickly become the victims of "post-truth" era with its negative consequences to the quality of society.
- **Application creativity** serves as a basis for building bridges between the theory in course contents and their application in real life. The employers expect the students to face and to solve practical problems from the very first day they join their company. At the same time, if the universities do not train them for these skills, the graduates will be sufficiently educated but disoriented, because they will not be proficient in recognizing the keys to the solutions. It implies that their educators should not only be trained in these skills but also demonstrate them – and be valued by them.
- **Creativity in teaching and learning** is a conjecture for organizing massive university education. The education of elites can be based on presumption that the students will understand the content because they belong among the most literate social group. At the same time, in the given moment in average 50% of high school graduates promotes to universities [7]. As the Gauss normal distribution holds for any country, the freshmen intellectual quality having their IQ 100 and above is reality. It implies that, the prevailing majority of freshmen are individuals with their standard intelligence; just a small portion belongs to the elite. To deliver university level of knowledge to the entire cohort presumes different knowledge

delivery skills compared to those applied to the elite education. As a result, educators should master them as well – and universities might orient themselves to specific groups of students.

## 5 The System Solution

The above discussion indicates that there are at least three additional area to evaluate educators' scholarship quality.

First, the educational skills should be valued much higher. The primary role of university educator is teaching, not research. Research has an important secondary and/or supportive role. It demonstrates that the educator is an expert in his/her field of specialization and can bring new knowledge – but to him/her, not directly to the students. So, his/her capability to transfer his/her gained knowledge for the form digestible by students requires a specific proof and evaluation. The proof can be demonstrated by various ways: by integrating existing pieces of knowledge into a new one(s), by applying them to a new invention, by developing a new teaching methodology or using a new non-traditional approach, etc.

All this means that a new set of evaluation criteria must be designed and developed. There is an appropriate candidate – European standards and guidelines [3]. Their main advantage is that the evaluation criteria are not dictated by the evaluator. They presume that the university itself sets up its vision and the way to it. The evaluator only verifies whether the vision corresponds to the required level of higher education and is adequately executed.

Such an evaluation/accreditation method supports the differentiation of universities, too. The university are free to form their visions as a mixture of the four types of scholarship. Let us exemplify potential outcomes of such differentiation:

- Stressing the *scholarship of discovery* will lead to forming a "research university" concentrating its efforts on discoveries and inventions that advance knowledge of humankind;
- A concentration on the *scholarship of integration* leads to the preference of liberal studies or their approximation. At many universities, they are offered as initial study programs to those students who have not made their final decision on their desired career yet.
- The attentiveness to the *scholarship of application* is also relevant to different fields. It is typical for universities of applied sciences where it addresses a variety professional and vocational study programs from engineering and construction to social care. At the same time, the research university students not belonging to the top or not eager for their academic career will also welcome the kind of knowledge and skills because they may bring them attractive jobs. The same holds for applications of humanities.
- Finally, the *scholarship of teaching and learning* should be developed at any and each university. At some of them ("teaching universities") it can be the core scholarship. Nevertheless, the systematic study of teaching and learning processes and their development should be a compulsory part at every tertiary institution. Due to

the advancement of technology, most courses can be enriched and facilitated by materials present on the Internet and/or delivered by the Internet, and the like.

Transitions from a current scholarship type to other one(s) are not simple and easy and proposals to implement them are not always welcome. For example, eight rectors of largest Slovak universities recently signed a memorandum [20] against the bill implementing first elements of "The Learning Slovakia" [4]. To reduce this kind of resistance, one has to stress that the transition is not compulsory. Its aim is to allow the universities to select their orientation, define their profiles, to form their long-term visions and to diversify themselves compared to the others.

## 6 Conclusions

The process of diversification of Slovak universities is just in its beginning. Let us now imagine that the legal conditions and the accreditation criteria will unblock the current ties and allow universities to build their own visions in accordance to the program "The Learning Slovakia" [4].

What can we expect to happen?

The *optimistic scenario* says that in a stepwise manner all universities will diversify. Due to their different visions and their systematic application, each of them will create its own profile. The profile will be publicly known and transparent. It means that the students and their parents will have the opportunity to select the optimal option(s) in accordance to the student's interest and intellectual capacity. Despite their different orientation, all universities will be of a good quality. The gained freedom will facilitate educators' creativity. As a result some of them become excellent. They will fully benefit from their new status of an "unoccupied" tertiary institution [21].

The *pessimistic scenario* starts with the presumption that the long history of obedience to totalitarian regimes as well as to the centralist Accreditation Commission rule made our universities inflexible and not capable of long-term planning. As a result, their management is unable to think independently, just expects the orders coming "from above" and only capable to obey and execute the orders (or to mimic their execution). This is the current situation at universities. Due to the absence of desire to change and a good will to accomplish it – the "culture of incompetence" will simple continue. No change will happen.

The realistic scenario presumes that not all universities will follow the pessimistic scenario. There will be some (or at least their sections) that will prefer a more progressive way. The adjective "progressive" does not necessarily means their radical move into a position among the World top 500. It rather means that they will change to Learning Organizations and their probability to prosper and develop will increase. Their development will not be free of failures. The learning processes in the complex environments require applying the method of trial and errors. They should concentrate their attention to the following directions:

- To specify and defend their individual positions at the "academic market", they must define their long-term vision in which they express their desired profile and preferred type(s) of scholarship.
- To redesign the internal structure in order to optimize the portfolio of their offered study programs; to downsize those with low quality and/or extensive competition and orient on those which can contribute to the development of their profile.
- To build up tailored positions of university knowledge workers in order to make "production processes" simple and more efficient. A potential structure of positions can be found for example in [22].

Only when all this happens and runs smoothly, the university will become a full member of the family of European higher education institutions. Even then, the institutions cannot interrupt its development. They must follow the trends contemporary and prosperous universities provide and are apt for their profile and function.

There are several factors supporting the authors' optimism. First, some the younger faculty have visited world leading universities and understand that the local habits are incompatible with those they witnessed abroad. Secondly, some older faculty starts understanding that the recent constant pressure on scientometrics does not bring positive fruit. The ministry of education has recognized the current "quality assurance" method is misleading, too. It has established an expert group to set up a long-term national vision "The Learning Slovakia". Its final version should be completed in the end of August. In our conference presentation, we will be capable to summarize how much of our proposed strategy has been included into this strategic document.

## References


1. Boyer, E.L.: Scholarship reconsidered: priorities of the professionate. The Carnegie Foundation for the Advancement of Teaching (1990). http://www.hadinur.com/paper/BoyerScholarshipReconsidered.pdf. Accessed 13 June 2017
2. Humboldt, W.: Űber die innere und äussere Organisation der hoheren wissenschaftlichen Anstalten in Berlin. In Gründungstexte Festgabe zum 200-jährigen Jubiläum der Huboldt-Universität zu Berlin. http://edoc.hu-berlin.de/miscellanies/g-texte-30372/229/PDF/229.pdf. Accessed 13 June 2017
3. Šima, K., Pabian, P.: Ztracený Humboldtův ráj. Slon, Praha (2013)
4. Burjan, V., Ftáčnik, M., Juráš, I., Vantuch, J., Višňovský, E., Vozár, L.: Národný program rozvoja výchovy a vzdelávania Učiace sa Slovensko – návrh na verejnú diskusiu, MŠVVŠ SR, Bratislava (2017). https://www.minedu.sk/data/files/6987_uciace_sa_slovensko.pdf. Accessed 13 June 2017
5. ENQA: Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), Brussels, Belgium (2015)
6. Academic Ranking of World Universities. Shanghai (2016). http://www.shanghairanking.com/ARWU2016.html. Accessed 13 June 2017
7. Kremský, P.: Talenty pre Slovensko, Podnikateľská asociácia Slovenska (2015). http://alianciapas.sk/wp-content/uploads/2015/12/Talenty-pre-Slovensko.pdf. Accessed 13 June 2017
8. Eurostat: Europe 2020 Indicators – Education. Eurostat (2016). http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_education. Accessed 13 June 2017)

9. Bratianu, C.: Reengineering the Romania Universities. J. Univ. Dev. Acad. Manage. **2**(3-4), 43–55 (2005)
10. Bratianu, C.: The learning paradox and the University. J. Appl. Quant. Methods **2**(4), 375–386 (2007)
11. Pritchard, R.M.O., Klumpp, M., Teichler, U.: Diversity and Excellence in Higher Education: Can the Challenges be Reconcilled?. Sense Publishers, Rotterdam (2015)
12. Višňovský, E. (ed.): Univerzita, spoločnosť, filozofia: Realita verzus hodnoty. IRIS, Bratislava (2014)
13. Dudáš, J.: Absurdity vysokých škôl a inteligencie na Slovensku. ETERNA Press, Bratislava (2012)
14. Hvorecký, J.: Testament vedca. Premedia, Bratislava (2015)
15. Jirsa, J.: Idea university, Academia, Praha (2015)
16. Chotaš, J., Prázný, A., Hejduk, T.: Moderní univerzita. Filosofia, Praha (2015)
17. Hvorecký. J., Kelemen, J.: Readings in Knowledge management. Iura edn., Bratislava (2011)
18. Hvorecký, J., Šimúth, J., Lichardus, B.: Managing rational and not-fully-rational knowledge. Acta Polytechnica Hungarica **10**(2), 121–132 (2013)
19. Cole, J.R.: Toward a More Perfect University. Public Affairs, New York (2016)
20. Stanovisko výskumných univerzít k návrhu novely zákona o vysokých školách a návrhu zákona o zabezpečovaní kvality vysokoškolského vzdelávania. Available at: http://uniba.sk/detail-aktuality/back_to_page/aktuality-1/article/stanovisko-vyskumnych-univerzit-k-navrhu-novely-zakona-o-vysokych-skolach-a-navrhu-zakona/. Accessed 13 June 2017
21. Halffman, W., Radder, H.: The academic manifesto: from an occupied to a Public University. Minerva **53**(2), 165–187 (2015)
22. Hvorecký, J.: University positions from the knowledge management's point of view. In: Proceedings of Schola 2016, Praha (2016)

# Quantitative and Qualitative Evaluation in Collaborative Learning

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**Abstract.** This research was developed considering the relationship that exists between the style of students learning evaluation and its influence on the development of collaborative learning. Nowadays education seeks to focus on collaborative processes, because they provide the student with the possibility of a holistic process. The proposed hypothesis suggests that quantitative and qualitative evaluation influences collaborative learning. The research was carried out in two periods: in 2014 at the Marqués de Selva Alegre School and in 2017 in the Manuela Espejo School. The methodology was applied to a population of 220 individuals, consisting of a survey for teachers and students with continuous items validated using Cronbach's Alpha. The objective was to demonstrate how the teacher's evaluation methods condition the type of work of the students, being this individual or collaborative. It was determined that the evaluation in the educational process must contain quantitative and qualitative elements, because it allows the execution of a cooperative work and generates meaningful learning; while maintaining an evaluation model focused only on quantitative instruments induces an individual practice and promotes rote learning.

**Keywords:** Quantitative evaluation · Qualitative evaluation
Meaningful learning · Collaborative learning

## 1 Introduction

Evaluation has always been linked to education as an instrument to measure student's learning level and it has been applied in any pedagogical model. It has been present in one way or another and has been placed in different levels of importance. Nowadays, two types of evaluation can be distinguished: the first, quantitative that focuses only on the measurement of knowledge in percentages, assigning a number that indicates the level of learning, valuing the final product that is knowledge; the second, qualitative that has a more holistic view evaluating the contents, skills, skills and learning process itself. The current educational context of Ecuador is developed within a collaborative and non-competitive framework as in the past, allowing students not only to learn content, but


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also to develop social skills, communicative and leadership skills, capable of responding to the labor demands of a globalized world. In this scenario, education should focus on promoting collaborative work, developing the cognitive, attitudinal and procedural knowledge in a context of equality and social justice.

Hence, the state of the art is developed, where theoretical variables are studied. In the methodological part, the instruments of data collection are presented, two surveys being validated by Cronbach's Alpha, a pre and a posttest to give validity to the instruments and a semi-structured interview that validated its internal consistency through judging value judges with Likert scales. The processing of the information is evidenced by statistical tables of the relevant dimensions.

## 2 State of the Art

The qualitative evaluation, unlike the quantitative one, comes from the humanistic current. It has a more integrative view of the subject and learning, and takes into account not only the possession of knowledge but also the way in which each student acquires it and applies it academically and contextually, that is to say, it involves the meaning of the learning and the process of appropriation of these [1]. The assessment of student learning at all levels of training is always under analysis and changes are introduced in the more formal fields, however, many of the evaluation aspects have been maintained over time.

Qualitative assessment has an individualized approach, recognizing that educational contexts and settings are unique and their outcomes are important in that particular context evaluated [2]. This assessment assigns a rating represented in number or letter that by itself has no value without the contextualization within the educational process that the student has lived [3]. The use of qualitative assessment allows teachers to measure students' progress and relate their cognitive growth to attitudes toward tasks that are often not taken into account when registering a grade. Cooperation in the classroom should be understood as a process and not as an action that is limited to the work of groups [4].

Developing cooperative processes in learning is necessary at all levels of education, because it is when more information is captured to form the perception of the world and its relation to it. Learners will be educated in an environment of cooperation without competences, where the common good is the main goal and there are no pressures to obtain certain qualifications. This will allow the students to begin a process of self-discovery of their skills without fear of being judged, implying an active collaboration of the student in their learning, making this a holistic, collaborative and meaningful development.

In order to achieve this work, teachers have several strategies to provide students with common objectives so that they can work towards them, so that each member of the group is responsible for the whole process and the success of the whole group. These activities should be based on constructivist learning, where students are the focus of the educational process [5].

## 3 Methodology

In order to identify the different aspects of the students' learning process, a survey was developed because it allows exploring, describing and predicting the variables of the study. Initially, the survey was addressed to the whole population defined by 90 students and 20 teachers of Marqués de Selva Alegre School, which was then replicated in the Manuela Espejo School to a population of equal size; being the total population of 220 individuals. The student questionnaire consisted of 18 items, the first ten items evaluated oral and written tests and participation in class. The following eight items evaluated the organization of the classroom, levels of cooperative work, individual work and type of school activities. The teaching questionnaire was elaborated with the same theme, adding two questions about micro-curricular planning.

An interview was conducted with the principals of the Marqués de Selva Alegre and Manuela Espejo schools to obtain qualitative information on the teaching process that is developed in the context of analysis. The interview was constructed with 10 questions about the social and educational context of the students and teachers of the institution.

In order to validate the information of the survey, we chose to use Cronbach's Alpha Consistency Assessment because the questionnaire was composed of continuous items addressed to students and teachers of the institution. Where the following variations were obtained:

Table 1 shows the variation of the items in relation to the total variance of response of the questionnaire addressed to the students of the Marqués de Selva Alegre and Manuela Espejo Schools. This instrument contains 18 questions. And we proceeded to apply the formula to obtain the Cronbach Alpha obtaining a value above 0.773 in the manual analysis as shown below:

$$\alpha = \frac{18}{18-1}\left[1 - \frac{\sum 38,956}{165,263}\right] = 0,773$$

**Table 1.** Validation of the survey of the students of the two institutions

| Descriptive statistics | | | | | |
|---|---|---|---|---|---|
| | N | Variance | | N | Variance |
| **Ítem01** | 90 | 1,771 | **Ítem10** | 90 | 2,092 |
| **Ítem02** | 90 | 2,49 | **Ítem11** | 90 | 2,265 |
| **Ítem03** | 90 | 1,93 | **Ítem12** | 90 | 2,183 |
| **Ítem04** | 90 | 2,085 | **Ítem13** | 90 | 2,236 |
| **Ítem05** | 90 | 2,137 | **Ítem14** | 90 | 2,274 |
| **Ítem06** | 90 | 2,118 | **Ítem15** | 90 | 2,164 |
| **Ítem07** | 90 | 2,138 | **Ítem16** | 90 | 2,252 |
| **Ítem08** | 90 | 2,288 | **Ítem17** | 90 | 2,226 |
| **Ítem09** | 90 | 2,235 | **Ítem18** | 90 | 2,07 |
| **Sum: 165,263** | | | | | |

In the same way, the information collected from the teachers of the Marqués de Selva Alegre and Manuela Espejo Schools was presented in Table 2 in relation to the variances obtained in their response for the consistency check.

$$\alpha = \frac{18}{18-1}\left[1 - \frac{\sum 35,779}{173,818}\right] = 0,803$$

**Table 2.** Validation of the survey of teachers of the two institutions

| Descriptive statistic | | | | | |
|---|---|---|---|---|---|
| | N | Variance | | N | Variance |
| **Ítem01** | 20 | 1,958 | **Ítem11** | 20 | 1,832 |
| **Ítem02** | 20 | 2,147 | **Ítem12** | 20 | 2,463 |
| **Ítem03** | 20 | 1,147 | **Ítem13** | 20 | 1,516 |
| **Ítem04** | 20 | 2,050 | **Ítem14** | 20 | 2,303 |
| **Ítem05** | 20 | 2,471 | **Ítem15** | 20 | 1,292 |
| **Ítem06** | 20 | 1,629 | **Ítem16** | 20 | 2,568 |
| **Ítem07** | 20 | 2,379 | **Ítem17** | 20 | 2,011 |
| **Ítem08** | 20 | 2,239 | **Ítem18** | 20 | 2,050 |
| **Ítem09** | 20 | 2,050 | **Ítem19** | 20 | 2,642 |
| **Ítem10** | 20 | 1,674 | **Ítem20** | 20 | 1,945 |
| **Sum: 173,818** | | | | | |

In both cases, when the Cronbach's Alpha is applied the values obtained are higher than 0.7 demonstrating the internal consistency of them to collect information (Table 3).

**Table 3.** Validation of the interview to the directors of the institutions

| Scale of valuation of the item according to the experts | | | | | |
|---|---|---|---|---|---|
| Question | Judge 1 | Judge 2 | Judge 3 | Judge 4 | Judge 5 |
| P1 | 5 | 5 | 5 | 5 | 5 |
| P2 | 4 | 4 | 5 | 4 | 5 |
| P3 | 5 | 4 | 4 | 4 | 5 |
| P4 | 5 | 5 | 5 | 4 | 5 |
| P5 | 4 | 5 | 5 | 4 | 4 |
| P6 | 5 | 3 | 4 | 5 | 5 |
| P7 | 5 | 5 | 4 | 5 | 5 |
| P8 | 5 | 4 | 5 | 5 | 5 |
| P9 | 5 | 5 | 5 | 5 | 5 |
| P10 | 5 | 5 | 4 | 4 | 5 |
| Total | 48/50 | 45/50 | 46/50 | 45/50 | 49/50 |
| Media | 46,6 | | | | |

For the validation of the semi-structured interview addressed to the directors of the Marqués de Selva Alegre and Manuela Espejo School a matrix based on a Likert scale was used where the judges gave their opinion on the content and design of it, obtaining an average of 46.6 points out of 50.

## 4 Evaluation of the Results

Table 4 shows the results of the pedagogical practice of students and teachers in the two institutions studied, in the Marqués de Selva Alegre School in 2014 and in the Manuela Espejo School in 2017. It is demonstrated that the teaching exposure is reduced by 16.36% in the Manuela Espejo School compared to the Marqués de Selva Alegre School. In the same way, the activities developed in the books decreased by 10.27% during the analyzed periods, while the application of group work increased considerably by 23.64%. It demonstrated a change of tendency in the performance of school activities in the classroom during the time that the research was developed and that processes of qualitative evaluation were being used most of the time.

**Table 4.** Methodology of the pedagogical practice of teachers and students of the two institutions

| Answer | Marqués de Selva Alegre School 2014 | | Manuela Espejo School 2017 | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Teaching exposition | 65 | 59,09 | 47 | 42.73% |
| Book activities are resolved | 39 | 35,45 | 31 | 28.18% |
| Team works | 6 | 5,45 | 32 | 29.09% |

Table 5 shows results on the class evaluation in the Manuela Espejo School investigated in 2017, evidencing a greater activation of knowledge, with a difference of 13.64% in comparison with the Marqués de Selva Alegre School studied in 2014; oral evaluations have a minimum variation of 0.91% in their application. In the Marqués de Selva Alegre School in 2014 there were teachers who did not perform any kind of class evaluation, with 14.55% of the respondents, an element that disappears in 2017 in the Manuela Espejo School because all Teachers did some sort of class evaluation.

**Table 5.** Classroom evaluation of teachers on students of the two institutions

| Answer | Marqués de Selva Alegre School 2014 | | Manuela Espejo School 2017 | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Activation of knowledge | 32 | 29,09% | 47 | 42,73% |
| Oral evaluations | 62 | 56,36% | 63 | 57,27% |
| Do not evaluate processes | 16 | 14,55% | 0 | 0,00% |

Table 6 shows the results of the evaluation that composes the curricular block present in the two schools, in 2014 block assessments were usually developed through the revision of school tasks, while in 2017 the percentage of teachers who evaluated school tasks is reduced to 15.45%, since the tasks are carried out in a directed way in the classroom. An opposite trend is shown in the objective tests that for the year 2017, the number of teachers who applied this technique increased by 39.10%. The performance in class did not have a difference as significant as the previous techniques evaluated increasing by 2.73%.

**Table 6.** Evaluation of the curricular block of the teachers on the students of the two institutions

| Answer | Educational unit Marqués de Selva Alegre 2014 | | Educational unit Manuela Espejo 2017 | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequencya | Percentage |
| Review of homework | 63 | 57,27 | 17 | 15,45 |
| Objective tests | 28 | 25,45 | 71 | 64,55 |
| Class action | 19 | 17,27 | 22 | 20,00 |

For the verification of the hypothesis the quantitative and qualitative evaluation influences on collaborative learning, the Chi-square test was elaborated in the two analyzed cases, obtaining as final decision that for four degrees of freedom and a level of significance $\alpha = 0.05$ and since the Chi-square value calculated (50.09 for the first case and 107.65 for the second case). It is greater than the chi-square tabular (9.48) the hypothesis is accepted as true.

## 5 Conclusions

The educational institutions evaluated have two different teaching styles. In the case of the Marques de Selva Alegre School, a traditional teaching methodology is presented, where the teacher is the center of the process and the student must construct an individual work that will be evaluated only with quantitative instruments, providing biased training of the curriculum, by not taking into account aptitudes, values and procedures. In the same way, the verification of the learning achieved by the students is limited to perform a test from time to time according to what the Law and School Regulations of Ecuador establishes, obviating the global phases of learning.

From the results obtained in this research, it is shown that in the Marques de Selva Alegre School, in the year 2014 59.09% of teachers frequently used expository or traditional teaching methods and 5.45% of them apply group learning techniques. The evaluation in class consisted of oral tests in 56.36% of the information collected, and 29.09% made a previous assessment of knowledge and 14.55% of teachers did not develop any type of evaluation. While performance-based skills block assessments are based on the task review in 57.27% of the total and the objective tests in a 25.45% and only 17.27% of the teachers take as element of evaluation the performance in class.

In the case of the Manuela Espejo School investigated in 2017, there is a clear change in methodology compared to the Marques de Selva Alegre School analyzed in 2014.

**Group work was emphasized** (23.64%) with a process within the classroom of qualitative class (16.37%) that develops social skills, leadership and provides a more holistic training of the human being. Despite this fact in the evaluation process, quantitative instruments (64.55%) were applied and the qualitative instruments were excluded. However, the teaching process in the school is presented closer to the reality of the objectives that have been raised from the government of Ecuador on what is wanted to achieve in education and in their processes.

From the results obtained in this research it is shown that in the Manuela Espejo School in the year 2017 29.09% of teachers used teaching collaborative learning methods and 42.73% used traditional techniques such as teacher exposure, and 28.18% used problem solving as a learning practice. The evaluation in class was made with oral tests in 57.27%, 42.73% made an activation of knowledge. While the curricular block assessments were based on the task review in a 15.45% of the total and the objective tests in 64.55% and only 20.00% of the teachers took as an evaluation criterion the performance in class.

Of the two schools analyzed, the Marques de Selva Alegre School presumes an individual and clearly quantitative teaching and evaluation process, while the Manuela Espejo School presents a more group teaching process (23.64%), and lower average of quantitative evaluation (16.37%). The purpose of the research is not to question the quantitative methodology in the learning, but to show it as one of the elements that must be joined to the qualitative methodology of the learning. It will provide a complete education to the students, without this being synonymous of exclusion or grouping students between suitable or non-suitable. The educational process is complex and difficult to understand, so we believe that limiting this process to obtaining a desired grade is most advisable.

## References

1. Morán, P.: La evaluación cualitativa en los procesos y prácticas del trabajo en el aula. Universidad Nacional Autónoma de México (2012)
2. Ortíz, E.: Epistemología de la Investigación Cuantitativa y Cualitativa: Paradigmas y Objetivos. Revista de Claseshistoria, pp. 1–23 (2013)
3. Cruz, F., Quiñones, A.: Importancia de la evaluación y autoevaluación en el rendimiento académico. Zona próxima, pp. 96–104 (2012)
4. Lillo, F.: Aprendizaje colaborativo en la formación de pregrado. Revista de Psicología UVM **2**(4), 109–142 (2013)
5. García, A., Basilotta, V., López, C.: Las TIC en el aprendizaje colaborativo en el aula de Primaria y Secundaria. Comunicar **42**, 65–74 (2014)
6. Ley Orgánica de Educación Intercultural: Ley Orgánica de Educación Intercultural (31 de 03 de 2011). Recuperado el 10 de abril de 2016, de Ley Orgánica de Educación Intercultural. http://www.evaluacion.gob.ec/wp-content/uploads/downloads/2015/06/Anexo-b.-LOEI.pdf
7. Constitución de la República del Ecuador: Ministerio de Educación del Ecuador (20 de octubre de 2008). Recuperado el 28 de 06 de 2015, de Ministerio de Educación del Ecuador. http://educacion.gob.ec/wp-content/uploads/downloads/2012/08/Constitucion.pdf
8. Canabal, C., Castro, B.: La evaluación formativa: La utopía de la educación superior? Pulso **35**, 215–229 (2012)

9. Carranza, G.: Docencia, discurso y evaluación colaborativa. Reencuentro, pp. 135–145 (2008)
10. Gamboa, R., Castillo, M.: La evaluación cualitativa en el campo social y en la educación. Posgrado y Sociedad **13**(1), 45–60 (2013)
11. González, J.: Una mirada del trabajo colaborativo en la primeria desde las representaciones sociales. Ra Ximhai, 115–134 (2014)
12. Mejía, O.: De la evaluación tradicional a una nueva evaluación basada en competencias. Educare, 42–58 (2012)
13. Moreno, I.: Docentes de educación básica y sus concepciones acerca de la evaluación en matemática. Revista Iberoamericana de evaluación educativa **1**(1), 140–154 (2008)
14. Pereira, J.: Evaluación, medición o verificación de los aprendizajes en el aula: Un estudio de caso en el Colegio Humanístico Costarricense de Heredia. Educare **19**(2), 405–428 (2015)

# Traditions and Experience in Studying Metric Intellect in Students

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**Abstract.** Intellectual activity is the leading employment for the students. The success of learning depends on the intellectual level, while there is a reciprocal influence of the learning process on the development of the students' intellectual potential. This research was performed with the purpose of comparing the level and structural parameters of intellect in modern Russian students and in the students of the '70s. We also compared the intellectual parameters of modern students in the engineering and liberal arts education, as well as the gender specific difference. The study was based on the Wechsler Adult Intelligence Scale (WAIS) method, and involved 1,040 students of Russian universities. It was discovered that no significant difference exists between the integral full-scale IQ parameters of the modern students and the students of the '70s, while there is a significant difference in the structural parameters determined by the educational specialty. We have come to a conclusion that the professional orientation has a stronger effect on the intellectual level and structure than the gender identity.

**Keywords:** Metric intellect · Special intellectual abilities · Professional area

## 1 Context

Based on the National Statistics (Rosstat) data Russian colleges and universities are providing education to around 5 million students. Every generation of students deals with different training methods and processes, as well as the updated requirements imposed by the educative process. The requirements and the expectations of the potential employers change too. That situation makes obvious the difference in styles of training that different generations have. The developmental psychology has evolved a notion of "students' age", which may have an artificial nature from the theoretical viewpoint, but also reflects the need to differentiate and study the multi-million social group of students.

Among numerous aspects of interest under the exploratory approach to the students' age, the study of metric intellect in students stands apart, since the intellectual activity is the leading and most significant function for the students [1, 2, 6, 7]. It is widely recognized that the intellectual development is tightly related to education, while the intellectual maturity is assessed with the use of the criteria related to the volume and level of knowledge within the framework of the education system existing in a certain


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social and historic period. At which life stages is the adult most receptive to learning and information processing? Which periods of mature age may be recognized as optimal for intellectual development? What are the metric intellect indices in students? For professors these questions are related to the search of teaching methods, oriented at revealing the intellectual potential of students. For students they are related to their personal interest in upgrading their intellect.

## 2 Approaches

Since fifty years ago, when the State University of Leningrad (now State University of St. Petersburg) launched the Department of Psychology (1966), the students have become one of the major subjects of research. Researchers guided by Boris. G. Ananiev defined the main directions in studying the student's psychology. The individual biologically oriented approach required to search and describe the qualities determined by the genetic background and the inherited disposition of the person, which act as certain development resources. The psychological approach per se was related to studying the specifics of the psychical processes, conditions, and personal attributes of students. The social approach is oriented at the specifics of studying students as a special social group, which has its peculiarities and specific functions.

The practical orientation of these studies should be noted. The students as a subject of research were not isolated from the educational and development environment, but were studied along with this environment interacting with it. Besides, the experimental results were implemented soon and were checked many times. A peculiar feature of this work was that the psychological and social aspects of the students' life were studied dynamically at all development stages from the high school graduate to the university graduate. The applied longitudinal approach allowed to track the changes in the factors of interest for specific students and determine not only the typological, but also the individual development trends.

Among the data obtained a special emphasis should be given to the data related to the changes in the quantitative and qualitative indices of the students' metric intellect in the course of their study at the university. It is worth mentioning that the compared intellect indices were obtained from the same students at their first year and their fifth year. As per the obtained data [4], 52% of the tested students showed an intellectual growth in the course of studies, while 44% had it unchanged. Finally, 4% (in other university groups 6–8%) of students demonstrated an intellectual decrement in the course of university studies.

It was the latter group that drew the attention of the researchers. The major factor that influenced the intellectual decrement got the working title of "mental laziness". Lack of preparedness to bear intellectual strain, to intellect trainability, mechanical overlearning without mental processing, "mirroring" of information, which excludes an active intellectual activity, all those are the accompanying signs of mental involution. Thus was established an obvious need for trainability in the course of brain work. Alertness and independence in obtaining and processing information are extremely important not only to grow, but also to maintain the achieved intellectual development level.

Grouping, classification, establishing logical ties, use of recall techniques are very important and dynamic parameters, related to the conversion of knowledge into intellectual proficiency.

The notion of "cost of intellectual strain", which reflected the fact that processing information and making a decision are accompanied by certain body power consumption at the physiological, biochemical and psychological levels.

Unfortunately, the recent 10–15 years have witnessed an evident decline in the research interest towards the students' psychology in Russia. In the numerous publications pertaining to the university topics we find mostly general reflections on the processes occurring in the students community. These descriptions tend to get further and further away from the real student, and are seldom based on research data.

## 3 Goals and Objectives

This research focused on how the metric intellect measured in students have changed in the past forty years. We had at our disposal the results of the students' intellect study carried out forty years ago at Leningrad (St. Petersburg) universities. The objectives consisted in reproducing the study scenario of 40 years ago, which would provide a possibility to compare the quantitative and qualitative parameters of the metric intellect in students of different generations. Besides, we set the task of comparing the parameters of interest in modern students, belonging to the engineering and to the liberal arts areas of education, and also comparing the men's indices with those of women.

## 4 Methods and Methodology

Theoretically the study was based on the principle of historism and cultural and historic conditioning of the consciousness (L.S. Vygotsky, A.N. Leontyev and others), the developmental principle (B.G. Ananiev, L.S. Vygotsky, S.L. Rubinshtein, B.F. Lomov, E.F. Rybakov and others) [1], the educational (M. Feuerstein, R. Fisher, A.W. Staats) [8] and information approach (H.J. Eysenk, E. Hunt, R.J. Sternberg) [3, 5, 9, 10] to studying intellect.

The methodology of the research was based on the principles of the integral psychic organization of the personality and the special place of the intellect in its structure. The comparative method was the main method of organizing the study. Wechsler Adult Intelligence Scale (WAIS) [11] was used as an empirical testing method. The statistical processing involved the Student's t-test, Mann-Whitney U-test, as well as the Pearson correlation analysis.

The sample group of the students of the '70s counted 800 persons who studied in the engineering or in the liberal arts areas. The sample group of modern students included 240 persons aged 20–22 (125 men, 115 women; 130 engineering students, 110 liberal arts students). The study was carried out in 2013–2016. The tests were applied individually and continued from 1 to 2 h depending on the test subject's performance.

## 5 Results

In order to answer the first question of how the metric intellect indices in students have changed during the past forty years, we performed a comparative analysis of the metric intellect indices in students of the '70s and of the modern students. We compared the cumulative scores (Full-Scale IQ, Verbal IQ, and Performance IQ), as well as the results of individual subtests of the verbal and performance scales (Figs. 1 and 2).

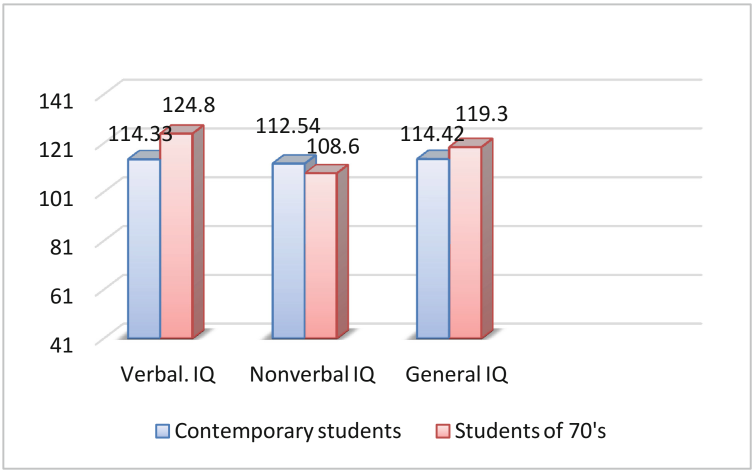


**Fig. 1.** Average values of cumulative intellect scores of modern students and the students of the '70s (WAIS test)

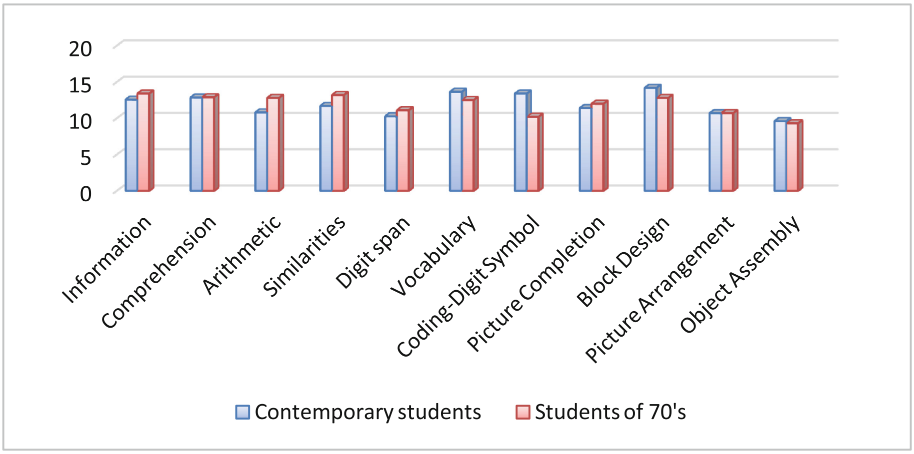


**Fig. 2.** Average values of partial intellect scores of modern students and the students of the '70s (WAIS test)

First of all we wish to state that the cumulative full-scale IQ index of the studied group and of the students of the '70s is within the "good standard" level, however, the spread of scores within the group of modern students is much higher. The structural profiles of the modern students and those of the students of the '70s are similar in that the Vocabulary and the Information parameters were dominating over the Attention focusing and the Working memory in the Verbal intellect structure, while the spatial inference level dominated over the Heuristic judgment and over the ability to refer the part and the whole in the performance intellect structure.

The modern students compared to the students of the '70s have demonstrated much lower scores of the verbal intellect, mostly due to the decrease in the general competence and in conception thinking. As for the performance intellect level, the fact stands out that different tendencies act there among the students in the engineering and the liberal arts areas of education. The modern liberal arts students compared to the students of the '70s lack a material diversity in the performance intellect level ("average standard" category). The engineering students show much higher indices of performance intellect compared to the students of the '70s, mostly due to the higher results in the hand-eye coordination and the visual synthesis. Consequently, we can state that the liberal arts students showed an expressed verbalization of intellect, while the engineering students manifested a leveling of the verbal and performance intellect parameters. The results of the Kohs Block Design Test need to be specifically emphasized, which testify to the adaptiveness related to the changes in the three dimensional perception conditions. This parameter has grown significantly in the modern students, and now it dominates in the performance intellect structure.

In order to answer the second question if there is a difference between the metric intellect indices in the modern students depending on the area of studies and on the gender, we compared the average results with the use of the Mann-Whitney U-test.

The average intellect indices in students from different professional areas are shown in Figs. 3 and 4.

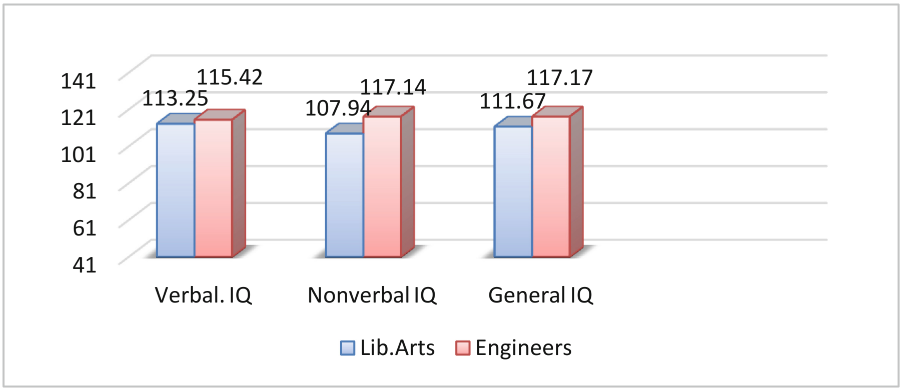


**Fig. 3.** Average values of cumulative intellect scores in the modern students from different professional areas (WAIS test)

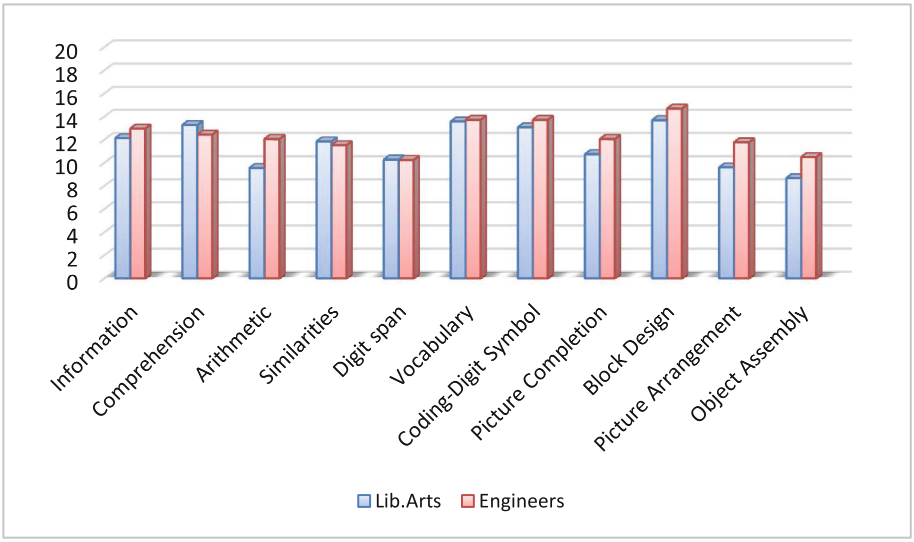


**Fig. 4.** Average values of partial intellect indices in the modern students from different professional areas (WAIS test)

The students of the tested groups have demonstrated a significant difference in the cumulative indices of performance and full-scale IQ. The engineering students have higher scores compared to the liberal arts students. No significant difference was discovered in respect of the verbal intellect.

In the verbal intellect structure a significant difference show the results on the Information subtest scale (competence, development level of main intellectual function such as memory and cogitation), and the Arithmetic subtest scale (attention focusing on complex intellectual problems) – here the results of the engineering students are higher. The liberal arts students have a higher score in Comprehension, which reflects a higher level of orientation in social situations.

Reviewing the professional difference in the students' performance intellect structure showed that both the cumulative indices of the performance intellect, and the results of all subtests have yielded a significant difference between the groups of interest, which signify an obvious advantage in the level of performance abilities in the engineering students. These parameters characterize the development level of the analytical and three dimensional perception capabilities, visual observation, heuristic judgment, consistency of practical reasoning, general adaptivity of the mental performance, and are extremely important for the creative work since they determine the person's self-consistency of thinking and the creative inclination. However, these features were developed worse in the tested group in spite of the fact that the average values are within the limits of the average demographic sample group standard. This level is obviously insufficient for the students: their values are around 12 points on the 20-point scale. Following illustrations review the gender specific difference in the intellect parameters in the modern students (Figs. 5 and 6).

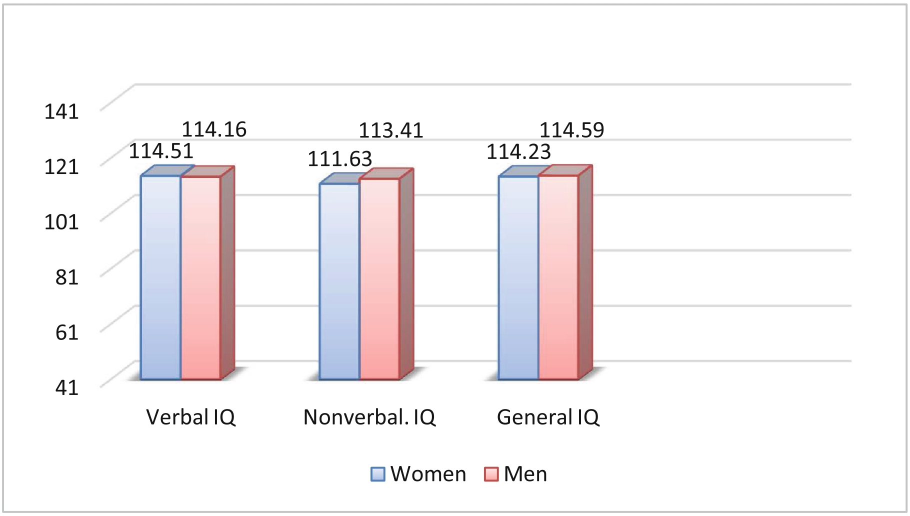


**Fig. 5.** Average values of cumulative intellect scores for women and men (WAIS test)

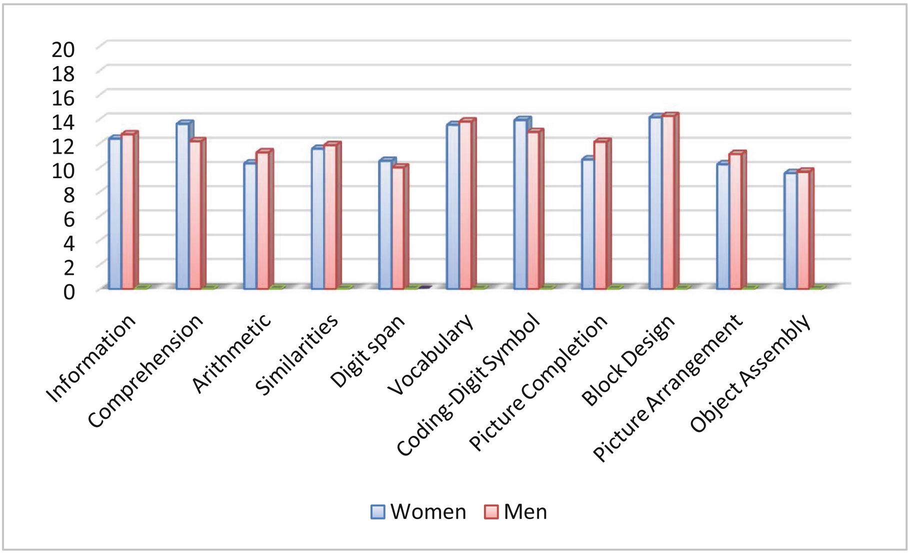


**Fig. 6.** Average values of partial intellect scores for women and men (WAIS test)

No significant gender specific difference was discovered in the cumulative scores for verbal, performance and full-scale IQ. The structure of the verbal intellect has demonstrated significant gender specific difference on the Comprehension subtest scale. This parameter is better developed in women. It should be noted here that the cumulative result on this scale reflects not only a success in solution of logical problems, but also the behavior effectiveness in various social situations. The results of the Digit span subtest are notably lower than the average values in the structure of the verbal intellect in men and women. That parameter indicates a low level of the working memory and vigilance in the students of the tested group. Women have the Arithmetic subtest parameter notably below the average values, which signifies a decreased attention focusing in solution of intellectual problems. This parameter shows the ability to achieve success in critical situations, including the situation of exam.

Reviewing the gender specific difference in the students' performance intellect structure we found that the results of the Block Design Test and the Digit Symbol Coding both for men and for women dominate in the performance intellect structure, however their level is within the average values range. Picture Completion score is notably below the average in the performance intellect structure for both genders, which signifies a rather low level of heuristic judgment in respect of three dimensional thinking. Men and women show similar scores in the intellect development level. However the following parameters differ significantly: observation (Symbol Search index) is better developed in men than in women, while the hand-eye coordination parameter (Digit Symbol Coding) is reliably higher in women.

## 6 Conclusions

The experimental data prove that students need a sufficiently high level of intellectual development to study successfully. A lower level may be compensated by an elevated motivation and performance efficiency. However there is a limit beyond which the compensatory mechanisms do not help.

The process of the students' professional development is related to the development of special capabilities. It is obvious that the intellectual abilities required for the engineering area are different from those required for the liberal arts. A high level of the verbal intellect is needed for a successful acquisition of the professions in the liberal arts area. The metric intellect structure of the liberal arts students includes a width of cognitive interests, broad knowledge, a good linguistic proficiency and the ability to use it properly, the skill of correlating concrete and abstract notions.

The leading qualities in the structure of the intellectual abilities of the future engineers are determined, in the first place, by the high level of three dimensional perception and mental agility development. Besides, they need to have a performance intellect (operational and practical) of a high level.

Our study has shown that the full-scale IQ scores of the modern students and the students of the '70s are close and lie in the range of "good standard". However the structural parameters of the intellect have changed significantly. The level of the verbal intellect of the modern students has dropped, mostly due to a decrease in the general competence and conception thinking. The performance intellect scores dynamics show different tendencies for the engineering and the liberal arts students. The modern liberal arts students compared to the students of the '70s lack a material diversity in the performance intellect level. The engineering students show much higher indices of performance intellect compared to the students of the '70s, mostly due to the higher results in the hand-eye coordination and the visual synthesis. Consequently, we can state that the liberal arts students showed an expressed verbalization of intellect, while the engineering students manifested a leveling of the verbal and performance intellect parameters. The modern engineering students compared to the liberal arts students have reliably higher cumulative performance and full-scale IQs. They surpass the liberal arts students in competence and in attention focusing within the verbal intellect structure, and in practically all indices in the performance intellect structure.

The common intellectual "bottleneck" of the modern students is the verbal (speech) intellect closely related to the knowledge level. The decrease in general competence, conception and heuristic thinking, as well as the increase in the spread of individual intellect indices against the background of unified learning requirements are alarming signs. It is obvious that the learning process should be optimized on all levels including schools and universities.

The gender specific difference in metric intellect parameters is not observed as per the average values. However the indices variability range is much wider in the group of men, similar to the students of the '70s. This trend matches the other regularities obtained by other psychological and physiological data.

The obtained results carry inference that the professional orientation has a stronger impact on the intellect level and structure than the gender identity. We find it perspective to continue the study of the students' metric intellect not only in the context of their professional development, but also in the context of individual changes in the students' intellectual parameters during their university course. The data obtained may assist in substantiation of new syllabus and specific teaching methods.

## References

1. Ananiev, B.G.: Integration of various properties of Man. Some forms and levels of the integration. Totus Homo (Milan) **4**(2), 47–55 (1972)
2. Daseking, M., Petermann, F., Waldmann, H.: Sex differences in cognitive abilities: analyses for the german WAIS-IV. Pers. Individ. Differ. **114**, 145–150 (2017). https://doi.org/10.1016/j.paid.2017.04.003
3. Eysenk H.J. (ed.): A Model for Intelligence, p. 9. Springer, Berlin (1982)
4. Integrated Social Studies: L., p. 183. LGU Publishng House (1976)
5. Hunt, E., Lunneborg, C., Lewis, J.: What does it mean to be high verbal? Cogn. Psychol. **7**, 194–227 (1975)
6. Kranzler, J.H., Benson, N., Floyd, R.G.: Using estimated factor scores from a bifactor analysis to examine the unique effects of the latent variables measured by the WAIS-IV on academic achievement. Psychol. Assess. **27**(4), 1402–1416 (2015)
7. Pluck, G., Ruales-Chieruzzi, C.B., Paucar-Guerra, E.J., Andrade-Guimaraes, M.V., Trueba, A.F.: Separate contributions of general intelligence and right prefrontal neurocognitive functions to academic achievement at university level. Trends Neurosci. Educ. **5**(4), 178–185 (2016)
8. Staats A.W.: Learning and Cognitive Development. University of Chicago Press, Chicago (III) (1970)
9. Sternberg, R.J.: Inside intelligence. Amer. Scientist **74**(2), 137–143 (1986)
10. Sternberg, R.J.: The Triarchic Mind: A New Theory of Human Intelligence, New York (1988)
11. Wechsler, D.: Manual for the Wechsler Adult Intelligence Scale. Psychological Corporation, New York (1955)

# Learning Culture and Diversity

# Factors and Barriers of Inbound International Student Mobility in Russia

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**Abstract.** Global integration and globalization in politics, economics and culture expand international contacts and result in higher education internationalization through export of educational programs and academic mobility. International student mobility is a complex, controversial and dynamic process. There is more global data on inbound than outbound student mobility. According to UNESCO Institute of Statistics, the number of internationally mobile students more than doubled from 2 to 4.3 million in the period between 1999 and 2014. Russia hosts 5% of the total number of mobile students; most of them come from Asia, the region which traditionally demonstrates the highest interest in and demand for the Russian higher education. The paper aims at distinguishing the pull factors and barriers (push factors) of inbound international student mobility in Russia by summarizing the experience of one of the leading engineering universities through analyzing the statistics and sociological survey results. The authors draw their conclusions on inbound academic mobility dynamics and give their recommendations on improving its intensity.

**Keywords:** Higher education internationalization
Inbound international student mobility · Students

## 1 Introduction

Globalization and integration in different spheres of human activities including politics, economics and culture expand international contacts. As leaders in education internationalization research, Altbach and Knight [1] state, in order to continue this discussion, it is important to accept a nonideologial definition to globalization as the flow of values, ideas, people, knowledge and etc., across borders having multiple effects on education. Thus, globalization results in higher education internationalization through export of educational programs, joint research and development projects, academic mobility of students and faculty members.

International academic mobility is a complex, controversial and dynamic process [2]. The analysis of the available data shows that it is hard to find information on faculty mobility due to their individual tracks and multiple peer-to-peer contacts. There is much more global data on inbound student mobility.


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According to one of the leading researchers in education internationalization, Caruso and de Wit [3], the number of international degree-seeking students is not only a constituent of internationalization, but it is an important manifestation of how universities become more international.

The data of the UNESCO Institute of Statistics [4] shows that the number of internationally mobile students more than doubled from 2 to 4.3 million in the period between 1999 and 2014. However, only few countries account for the biggest flow of inbound students. Thus, the largest numbers of students are hosted by the USA (26%), UK (15%), France (10%) and Germany (10%).

Russia hosts 5% of the total number of mobile students; most of them come from Asian countries, including the former USSR partner countries such as Vietnam, India, China. The Central Asian region traditionally demonstrates the highest interest in and demand for the Russian higher education.

Russian universities use different approaches to internationalization and development of inbound student mobility including networking [5, 6], direct peer-to-peer contacts with partners in other countries [7], narrowing down collaborations to certain levels of education, e.g. associate degrees, bachelor degrees or master degrees [8], developing cross-cultural competencies of the students [9]. For engineering universities, the problem of student academic mobility is also related to the level of research, links with industry, and contacts with the industrial partners from other countries [10, 11].

## 2 Purpose

The paper aims at finding the factors and barriers of inbound international student mobility in Russia by summarizing the experience of one of the leading engineering universities through analyzing the statistics and sociological survey results. The hypothesis of the study is that the inbound student mobility can be intensified if we approach the problem at the local regional level. When developing the strategy to attract foreign students, the university should consider the interests of the local region where it is situated, including its internationalization policy and priority partner countries, economics and leading industries, migration policy, cultural links between the region and other countries.

Every region develops its own unique model of international collaboration, and education becomes an integral part of this model. Academic mobility can be viewed as a tool for social and economic development of the region. Thus, the host region can receive additional revenue as the tuition costs, highly qualified human resources out of those foreign students who stay in the region, and future ‘ambassadors’ of the region represented by the graduates who return to their home countries. At the same time, there are a number of obstacles for inbound student mobility due to which the numbers still remain low, including few opportunities in funding, restrictions on collaboration with a limited number of partner countries, and language barriers. The distinguished factors and barriers will contribute to student attraction strategy renewal to benefit the university and the region resilience.

## 3 Approach

The paper uses a regional approach to the inbound international student mobility problem in Russia. Depending on the regional challenges, different strategies should be used for balancing student mobility and finding the best solutions.

In the study, we chose one of the economically developed regions of Russia, with the leading chemical and petrochemical industries, the Republic of Tatarstan. The Republic is situated to the east of Moscow, in the central European part of Russia, at the confluence of the two big rivers, the Volga and the Kama. It is in a one hour flight from Moscow. The area of Tatarstan is 68,000 sq. km, and the population is around 3.8 mln. people as of 2011 statistics [12]. According to the 2016 data of the Ministry of Education and Science of the Russian Federation [13], there are 52 higher educational institutions in Tatarstan, including one federal status university, and two national research status universities. The number of students who study in Kazan is around 164,000 which makes 3.46% of the total number of students in Russia.

The leading industries in Tatarstan are petroleum and gas production and refinery, chemical industry, petrochemical industry, mechanical industry, textile and food production. Therefore, engineering professions are in the largest demand, and 37.5% of university degree programs are in engineering.

The unique characteristic of Tatarstan is the percentage of the traditionally Muslim people, the Tatar nation, which makes around half of the total population. This contributes to the internationalization strategies of the Republic which is very active in its international contacts, and, alongside with a large number of partners in Europe and North America, it develops efficient collaborations with the Asian countries. Collaborations in politics and industrial production lead to a large flow of international students to Tatarstan. Analysis of the Ministry of Education and Science of the Russian Federation data of July 2016 [12] shows that the region hosts 3.5% of the total number of foreign students in Russia and is in the top 5 according to this parameter. A significant proportion of those students come to Tatarstan to receive degrees in engineering. The percentage of foreign students in Tatasrtan universities offering degrees in engineering is shown in Table 1.

**Table 1.** Foreign students in Tatarstan Engineering Universities (2016 data [11])

| University | Percentage of Foreign Students |
|---|---|
| Kazan Federal University | 8.23 |
| Kazan National Research Technological University | 10.39 |
| Kazan National Research Technical University | 4.81 |
| Kazan State University of Architecture and Engineering | 3.56 |
| Kazan State Power Engineering University | 5 |

The largest percentage of foreign students study at Kazan National Research Technological University, therefore, we chose this university for a deeper analysis of the inbound international student mobility using the data from official reports of the university to the authorities and the results of a special survey.

The analysis of inbound students in Kazan National Research Technological University showed that their total number almost doubled from 2012 (1,180 sts) to 2016 (2,134 sts). Thus, as for 2016, the university hosts almost 30% of all the inbound foreign students in the region.

The majority of these students come from Central Asia countries, including 499 students from Uzbekistan, 487 students from Turkmenistan, 127 students from Kazakhstan, 278 students from Tadjikistan, 125 students from Kyrgyzstan, and 50 students from Azerbaijan. These data support the general trend in the Russian Federation where the majority of inbound student mobility comes from the ex-Soviet Union countries. However, this trend also proves the importance of the local culture for choosing the university in the region with half of the Turkic, traditionally Islamic population.

We developed and conducted a survey for these academically mobile students to find their attitudes towards study in Russia. The survey consisted of three blocks of questions:

- *the first block* included 12 closed personal questions relating to the sex, age, level of study, degree program, funding source, awareness of the global mobility funding programs;
- *the second block* included 12 Likert items to be evaluated according to a 10-point scale concerning the advantages and difficulties of study in Russia, the choice of the university, benefits of the chosen university, future career opportunities, and demand for graduates from Russian universities in home countries;
- *the third block* included 4 closed and open-ended questions on general impressions about the region where they study, changes in their world outlook and plans for the future.

The questionnaire was tested for validity and reliability and proved its efficiency. The survey was conducted anonymously; 200 students participated in it. We used statistical analysis to interpret the collected data. The analysis aimed at finding certain factors and barriers for study in Russia, and correlations between them in order to use them in planning and balancing the future flows of inbound students.

The *first block questions* gave general statistics: out of 200 survey participants:

- 76% were men and 24% were women;
- 56% were in the age group of 18–20, 34% aged 21–23, and only 8% aged 24–26;
- 66% had the period of residence in Russia under 3 years, 26% resided in Russia from 3 to 5 years, 6% – from 5 to 7 years, and only 2% over 7 years;
- 86% studied in the bachelor degree programs and 14% studied in the master degree programs;
- 46% chose degree programs in chemical engineering, 24% in mechanical engineering, 12% in ITs, and only 14% in humanities.
- 30% had work experience;
- 58% received funding from the Russian Government, 16% were funded by the employers, and 26% paid tuition themselves.

These results proved the demand for engineering degree programs among the inbound academically mobile students. Moreover, they showed the interest of the Russian Government in attracting foreign students and supporting them.

Another important trend is study funding from the employer. In our case, the survey participants gave details on their future employer, the State Company *Turkmenhimiya* (Turkmen Chemistry) which has very close links with Tatarstan industry. This supports our hypothesis on the regional approach efficiency.

The *second block questions* gave important information for drawing conclusions about factors and barriers of inbound academic mobility in Russia.

The majority of the survey participants supported the following advantages of receiving university degrees in Russia:

- high quality of education – 98%;
- high skilled and experienced faculty members – 90%;
- close links with industry – 86%;
- good opportunities for doing research – 84%;
- high quality laboratory equipment – 82%.

These advantages concern the most demanded degree programs. The majority of the survey participants evaluated the following degree programs as highly demanded at 8–10 points and 4–7 points, correspondingly, according to the Likert scale:

- technological machines and equipment – 90% and 10%;
- process flow and production automation – 88% and 12%;
- chemical engineering – 80% and 20%;
- information technologies – 80% and 20%;
- innovations in chemical engineering – 72% and 28%;
- nanoengineering – 78% and 20%;
- biotechnologies – 72% and 24%.

As you can see, none of the survey participants considered the first five of the listed degrees as being in a low demand.

The demand for these degree programs is closely related to the demand for professionals in the labor market. The survey participants considered engineers, chemists and programmers as most demanded in their home countries, this opinion received 8–10 points of the Likert scale by 88%, 78% and 72% of the respondents, and got 4–7 points of the Likert scale by 6%, 14% and 12% of the students, correspondingly. Economists and lawyers are less demanded in the Central Asian countries: only 48% and 50% of the survey participants gave them 8–10 points, correspondingly; 24% and 20% of the students consider these professions as not demanded in the market.

Thus, academically mobile students choose a foreign university to study in according to the degree programs it offers, this explains the largest percentage of foreign students at Kazan National Research Technological University offering degrees in different engineering programs highly demanded in the international market.

There are also other reasons for choosing a university. The majority of the survey participants evaluated the following reasons as highly important (8–10 points of the Likert scale) and important (4–7 points of the Likert scale), correspondingly:

- university rating – 82% and 14%;
- city status – 80% and 18%;
- political and national stability – 87% and 18%;
- nationalities in the region – 62% and 30%;
- economic, political and cultural links between home country and the region – 62% and 32%;
- compatriots in the city – 52% and 42%;
- good living conditions – 48% and 44%;
- opportunities to find a job – 46% and 46%.

All these choices speak of the safety importance in choosing the country and the university to study in, and this conclusion goes in line with research by Valeeva [2] showing that personal safety of international students is a crucial pull factor that has become a key issue in many countries.

The survey included a number of statements regarding the difficulties that foreign students face while studying at a Russian university. The statements were evaluated according to the Likert scale, and the results showed that the opinions of the students on these statements are very different (see Table 2).

**Table 2.** Difficulties foreign students face

| Difficulties | Points, Likert scale | | |
|---|---|---|---|
| | 0–3 | 4–7 | 8–10 |
| University rules | 34% | 32% | 34% |
| The Russian language | 36% | 28% | 36% |
| Contacts with faculty members | 36% | 16% | 48% |
| Contacts with other students | 34% | 18% | 48% |

Thus, analyzing the data given in Table 2, several conclusions can be made regarding the difficulties that foreign students face:

- the difficulties issue is very controversial and arbitrary; it largely depends on the personal traits and attitudes;
- any student can face any difficulties in very different spheres depending on circumstances;
- there are four issues in which around half of all students face difficulties, including contacts with faculty members, other students, housing and weather conditions.

When facing difficulties, 72% of the survey participants seek for help from their friends, 70% get receive help from their compatriots. Only 50% of the respondents answered that their teachers (university faculty members) can help them, while 12% of the students do not believe it. At the same time, 14% of the students do not believe that other students, groupmates, can help them.

In order to overcome and to prevent these difficulties, different activities can be implemented. Several options were suggested for survey participants, including: (1) celebrating cultural holidays of different countries; (2) organizing Russian cultural events; (3) gathering students from one country in one study group; (4) organizing sporting events. The fourth option received the highest support from the foreign students, 82% of them giving it 8–10 points Likert scale, and 14% - 4–7 points. The first and second options were highly supported and supported by 64% (32%) and 66% (30%) of the students, correspondingly. Only 52% of the students highly supported the idea of gathering all foreign students together in study groups.

Despite the difficulties, 89% of survey participants gave 8–10 points to the idea that they will be more competitive in the labor market than their peers who received their education at home universities; another 16% gave 4–7 points. At the same time, the statement that the Russian university graduates are more competitive in the labor market than their peers who studied in other countries, was evaluated at 8-10 points by 62% of the students, and at 4–7 points by 34% of the students.

*The third block questions* gave general information on the students' impressions about Kazan and their plans for the future. The students named the most important factors for choosing Kazan as the host city for their education: 42% of the survey participants named the positive city environment; 32% named positive attitude to foreigners and 20% named the presence of compatriots in the city. 28% of the survey participants would like to stay in the city after graduation, 40% do not want to stay, and 32% have not decided yet.

## 4 Outcomes

The analysis of the regional approach, general statistics and survey results allowed us to distinguish a number of objective, structural and subjective pull and push factors for inbound international student mobility in Russian universities to be used in balancing the student mobility flows.

The *objective factors and barriers* reflect the general state of the region, including regional economy, politics, science, education, culture, internationalization strategy. The survey showed the following objective push and pull factors:

- political and national stability in the region;
- culture and religion of the local population;
- economic, political and cultural links between the Russian region and student home country;
- compatriots in the city;
- good living conditions;
- opportunities to find a job;
- attitudes to foreigners;
- language of communication;
- weather conditions.

The *structural factors and barriers* show the university structure and its readiness for internationalization, including the university status, degree programs, foreign partners, language of study. The survey showed the following structural push and pull factors:

- university rating;
- quality of education;
- skills and experience of faculty members;
- close links with industry;
- demanded degree programs;
- opportunities for doing research;
- laboratory equipment;
- help and support from the faculty members;
- peer students;
- knowledge of the local culture.

The subjective factors and barriers reflect the personal readiness for academic mobility, including personal attitudes towards foreign culture, opportunities to find funding, world outlook, career plans. The survey showed the following subjective push and pull factors:

- funding opportunities;
- intellectual development;
- linguistic abilities;
- career interests;
- broad world outlook;
- readiness to travel;

Thus, the approach used was based on applying local regional internationalization strategies to universities, choosing a region and analyzing general statistics of inbound student mobility in it, choosing a particular university and analyzing its statistics, conducting a survey among foreign students in the chosen university, interpreting the data using statistical methods to distinguish factors and barriers to inbound international students mobility and correlations between them, giving recommendations on using these factors and barriers to balance the student mobility flows.

## 5 Conclusions

The study showed that most of the inbound international students in Russia come from Central Asian ex-Soviet Union countries. In choosing the place of study, many of them prefer the regions with a familiar culture where a lot of the population is traditionally Islamic. One of such regions hosting 3.5% of the total number of inbound students in Russia was chosen for the study.

The study revealed the following factors for the students to come to the region: a comfortable economic and political situation, positive attitudes towards foreigners, cultural and industrial links between home country and the Russian region, local societies of compatriots, university status, quality of education, quality of university staff, engineering and IT degree programs, future career opportunities, demand for graduates in home country.

At the same time, the study showed a number of barriers, including funding limitations, visa regulations, university rules, social problems related to accommodation and communication, and poor command of the Russian language.

By improving the factors and removing the barriers, we can increase the inbound international student mobility in the Russian universities so as to make a positive contribution to the regional economy and to the national economy in the long run. These results can be scaled up for the inbound international students from other countries and for other regional universities.

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## References

1. Altbach, P.G., Knight, J.: The internationalization of higher education: motivations and realities. J. Stud. Int. Educ. **11**(3/4), 290–305 (2007). https://doi.org/10.1177/1028315307303542
2. Valeeva, R.: Academic mobility is the main tool of the intercultural competence development of engineering students and scholars in China and Russia. In: Proceedings of 2013 International Conference on Interactive Collaborative Learning, ICL 2013 (2013). https://doi.org/10.1109/ICL.2013.6644721
3. Caruso, R., De Wit, H.: Determinants of mobility of students in europe empirical evidence for the period 1998–2009. J. Stud. Int. Educ., **19(**3) (2015). https://doi.org/10.1177/1028315314563079
4. UNESCO Institute for Statistics: Total inbound internationally mobile students. http://uis.unesco.org/indicator/edu-mobility-in-total. Accessed 20 May 2017
5. Ziyatdinova, J., Bezrukov, A., Sukhristina, A., Sanger, P.A.: Development of a networking model for internationalization of engineering universities and its implementation for the Russia-Vietnam partnership. In: Paper Presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana, June 2016. https://doi.org/10.18260/p.26808
6. Sukhristina, A.S., Ziyatdinova J.N., Kochnev A.M.: [Networking as a Form of Internationalization in Education: Case Study of KNRTU]. Vysshee obrazovanie v Rossii [Higher Education in Russia], no. 11, pp. 103–110 (2016). (in Russ., abstract in Eng.)
7. Kraysman, N.V., Valeeva, E.E.: Integration of KNRTU into the world community as an example of cooperation with France. In: Proceedings of 2014 International Conference on Interactive Collaborative Learning, ICL 2014 (2015). https://doi.org/10.1109/ICL.2014.7017886
8. Zolotoreva N.M., Oleynikova O.N.: [VET development in the context of internationalization]. Vestnik of Tver State Universty. Seriya; Pedagogika i Psikhologiya [Bulletin of Tver State University. Pedagogy and Psychology], no. 4, pp. 121–132 (2015). (In Russ., abstract in Eng.)
9. Gorodetskaya, I.M., Shageeva, F.T., Khramov, V.Y.: Development of cross-cultural competence of engineering students as one of the key factors of academic and labor mobility. In: Proceedings of 2015 International Conference on Interactive Collaborative Learning, ICL 2015, pp. 141–145 (2015). https://doi.org/10.1109/ICL.2015.7318015/SourceScopus

10. Ziyatdinova, J.N., Osipov, P.N., Bezrukov, A.N.: Global challenges and problems of Russian engineering education modernization. In: Proceedings of 2015 International Conference on Interactive Collaborative Learning, ICL 2015 (2015). https://doi.org/10.1109/ICL.2015.7318061
11. Ziyatdinova, J., Bezrukov, A., Sanger, P.A., Osipov, P.: Best practices of engineering education internationalization in a Russian Top-20 University. In: Paper presented at 2016 ASEE International Forum, New Orleans, Louisiana, June 2016. https://peer.asee.org/27236
12. Russian Federal State Statistics Service: All-Russian Population Census, vol. 1 (2010). (in Russian). Accessed 29 June 2012
13. Ministry of Education and Science of the Russian Federation. Informatsionnoanaiticheskiye materialy po rezultatam provedeniya monitorings effektivnosti deyatelnosti obrazovatelnyh organizatsiy vysshego obrazovaniya [Information and Analysis on the Results of Monitoring the Efficiency of Higher Educational Institutions] (in Russian). http://indicators.miccedu.ru/monitoring/_vpo/material.php?type=2&id=10608

# Female Participation in Engineering Fields: Successes, Challenges, and Recommendations in a Non-western Context

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**Abstract.** This paper describes a collaborative faculty-student research project examining female students' perspectives on their academic and social experiences studying engineering at an American branch campus in Qatar. It draws on data collected from a series of focus groups, an anonymous survey, and self-reflexive research team meetings. The experiences are discussed in relation to the university's institutional strengths and challenges in terms of supporting female students for working in engineering-related careers in the Arab Gulf and recommendations are given.

**Keywords:** Women in engineering · Women in STEM
Female engineering students · Women in the Arab Gulf
Education in the Arab Gulf

## 1 Introduction

Research on female participation in Science, Technology, Engineering and Mathematics (STEM) fields has been conducted almost exclusively within Western contexts. Shifting our focus towards under-researched geographical and cultural settings can help create more nuanced analyses of the presence and role of women in various environments. It is in this context that the Arab Gulf, a region undergoing tremendous socio-economic transformations, may contribute to the body of research focusing on the role of women in the Middle East, specifically in regards to fostering female participation in fields that have been traditionally dominated by men.

For UNESCO, "science and engineering hold important answers to key questions like climate change and sustainable development that we must address today […] especially in the developing world, where attracting more women to fields in which they are underrepresented must be a part of the solution" (UNESCO 2013). Despite the agency's call in the framework of the Millennium Development Goals, there are still numerous recurring challenges worldwide that relate to the participation of women in STEM. Some of the existing literature point toward the lack of role models, stereotypes and gender bias, workplace bias, and underrepresentation in leadership positions, as important challenges that negatively affect the advancement of women in STEM industries (Hill et al. 2010; McCullough 2011; Williams 2015).


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Within university contexts, underrepresentation among faculty, and discrimination against female faculty and students, have been identified as pressing challenges (Hopkins 1999; Robnett 2015; Sheltzer and Smith 2014). Furthermore, Moss-Racusin et al. (2012) explain that both female and male faculty members have been identified to exhibit gender bias. Their article explains that faculty often evaluate female undergraduate students lower than their male counterparts—pointing toward negative perceptions of women that contribute to little support and mentorship. In a similar research, Moss-Racusin et al. (2015), argue that this bias, although frequently unintentional or implicit, has become a major challenge that relates to widespread socio-cultural stereotypes. Gender bias in the university is thus associated with the development of diversity interventions and prejudice recognition and reduction.

While the percentage of female students within STEM fields in the Middle East is comparable to, and in occasions higher than in Western countries (UNESCO 2013), the status of women studying STEM fields has only been marginally researched. Engineering enjoys a particularly high social status in the region attracting female and male students alike (Baytiyeh 2013; Iversen 2016). In two studies based in Lebanon and the UAE (Aswad et al. 2011; Baytiyeh 2013), the authors explain that the potential for professional growth and interest in the field are the principal motivating factors encouraging their participants' decisions to pursue engineering as their studies.

The Arab Gulf region, in this context, distinguishes itself by having a higher enrollment in STEM among female than male students (al-Wazir, 2016). For instance, 60% of engineering university students are female, double the percentages in the U.S.A. and Europe (Durrani 2015). Texas A&M University at Qatar (TAMUQ), our specific context, became the second university in Qatar to offer degrees in engineering in 2003. Currently, approximately 41% of the entire student body is female and within certain engineering majors, the percentage of females is 60%. The high rates of enrollment among women are unfortunately not consistent with those of women entering the workforce after graduation. In the Middle Eastern context, only 1 in 5 women graduating with STEM degrees, is employed in their field. (Mannan 2016). When writing of this issue, Kantor (2016) asks: "if young college graduates in the Middle East and North Africa are being told they should not or cannot pursue a career in their field, how can we expect to see stronger representation of women in STEM?" This question becomes particularly relevant when looking at the relationship between the participation of women in the workforce, particularly in relation to STEM, and economic competitiveness and productivity (Fawwaz 2014).

Concomitantly, some research pertaining to the Arab Gulf has focused on the relationship between individuals and the economy, and society and culture. Aswad et al. (2011) argue, in the context of raising awareness and overcoming negative stereotypes about STEM, for the adaptation of policies to diverse local contexts. Employment expectations, support systems, and family connections, moreover, contribute to women's education and career path (Fawwaz 2014). Previous government efforts in the Gulf region include a 2015 UAE Government Summit promoting the role of women in STEM, and the creation of a UAE Gender Balance Council with a series of collaborations with the Women in Engineering Committee (Margheri 2016). The Women in Engineering Forum of the Gulf Cooperation Council (GCC) was held in Qatar in 2013.

Despite some positive developments, stereotyping, cultural norms, and working in male-dominated industries are still pressing challenges for female engineering students entering the job market. Aswad et al. (2011) have argued that national culture and traditions can be discouraging for women pursuing engineering degrees. Furthermore, various authors have focused on examining deterring aspects for women's participation in STEM. Qayyum (2012) argues that socio-psychological barriers prevent female engineers from putting their skills into action in the context of their STEM careers. Baytiyeh (2013) has argued that partly because of lack of self-confidence stemming from being within traditionally male-dominated fields, women in engineering fields are not sufficiently prepared to transform knowledge into product. Similarly, other authors have looked at sociocultural constraints (Durrani 2015); women leaving the field to raise a family (Kantor 2016; Mitchell et al. 2015); and exclusion, discrimination, and restrictions (Iversen 2016).

Sulaiman and AlMuftah (2015) explain, based on data from Qatar's public university, that despite having high retention rates among female engineering students, the university should still attract more female students to their engineering degrees. Notwithstanding socio-cultural obstacles, they argue, women in Qatar have shown to be better educated than men. In the context of access to education and economic development, the position of Qatari women is changing, with more and more entering the professional world, even within traditionally male-dominated industries.

Some broad recommendations to improve the status of women working in STEM fields include the implementation of gender quotas within nationalization policies and equalizing salary benefits (Mitchell et al. 2015). Particular recommendations for universities have focused on developing leadership and management trainings (Baytiyeh 2013); attracting mentors and role models (Kantor 2016); focusing on more positive peer connections (Robnett 2015); fostering social-psychological interventions (Nnachi and Okpube 2015); and developing career services, internship opportunities, and connections with alumni (Fawwaz 2014). All steps that can be taken to promote and ensure gender equality within STEM are nevertheless contingent on addressing restrictive socio-cultural barriers that negatively affect the experiences of female engineering students in Qatar and beyond.

It is within this context, that this paper sheds light on a self-reflexive project to investigate the experiences of being female and an engineering student in Qatar and the successes and challenges at an institutional level, as well as offers recommendations.

## 2 Project

During the spring of 2016, the Women's Faculty Forum (WFF) at TAMUQ hosted a panel discussion on campus about "real-life strategies for overcoming struggles as females in industry, business, and academia." The feedback from TAMUQ female students who attended was overwhelmingly positive, with many indicating how encouraging and inspiring it was for them to interact with alumnae working in high-level positions in their fields. It was clear from informal discussions with students that they face challenges as female engineering students and many desire more support and mentorship on how to overcome things like gender bias and fulfill their ambitions.

Considering this and in the context of high-impact educational practices, an engineering colleague and I proposed a collaborative faculty-student research project to develop and present recommendations on how to better support, encourage, and prepare our female students, especially our Qatari population, for working in engineering-related careers. As part of this project, we helped guide a small group of TAMUQ female students to have discussions on relevant literature, conduct focus groups, and develop and analyze an online survey to be completed by all female TAMUQ students. In addition, a survey to be completed by TAMUQ alumnae working in industry or academia is in progress.

In order to examine current student perspectives on the successes and challenges of being a TAMUQ female engineering student, the first part of our data collection included a series of focus groups with 6–8 current female students participating in each session. The questions revolved around why our students chose engineering and whether they are still satisfied with their choice, TAMUQ institutional strengths and weaknesses in terms of supporting our female students, experiences with professors and peers, and perceptions about challenges women face from society and industry in Qatar. The focus groups were transcribed verbatim and our student researchers helped to code the data and look for themes that seemed significant to the participants. Based on the findings of the focus groups, we worked with the students to design an anonymous survey to be sent to current TAMUQ female students. 100 responses were recorded out of the 231 female engineering students, which resulted in a 43.29% response rate. The majority of the students who responded were Qatari (57%). The students oversaw distributing and analyzing the survey responses and triangulating it with the focus group data.

The ultimate goal of the project was to explore TAMUQ's institutional strengths and challenges in terms of supporting our female students. After collecting and analyzing our data, our students came up with recommendations to help support, mentor, advocate for, and prepare our female students for greater long-term success in engineering careers.

By participating in this project, students engaged in many essential outcomes of high-impact educational practices. Students built their intellectual and inquiry skills by learning to ask relevant questions and develop social science research skills. At the same time, they conducted research and shared the results with their communities, which they then integrated and applied into a conference presentation and publication. This project also implemented some of the principles of A Whole New Engineer (Goldberg and Somerville 2014) in terms of making female students stakeholders in their own learning and having them contribute to developing recommendations for transformative educational experiences at TAMUQ.

## 3 Findings

In this section, we provide a brief overview of the findings of the focus group data (see Hillman et al. 2017, for a more thorough discussion of the focus group and survey data findings).

### 3.1 Why Our Students Chose Engineering?

In terms of why our students chose to study engineering, there were two main themes. Many mentioned a "passion" for fields such as mathematics or chemistry since an early age. Participants also discussed feeling the need "to prove" or "to show" something. Additionally, most of the participants' families expressed preference towards their daughters studying in fields other than engineering, particularly when it came to petroleum engineering. Their family members worried that as females, the participants would not be able to get jobs when they graduated and would thus, waste their education, or would be around only men in the field. Despite participants' families not being overly enthusiastic about their choice to study engineering, the participants all felt that their families were supportive of their decision in the end, but may still strongly guide their future career decisions.

### 3.2 Successes at TAMUQ

When we asked participants what they thought TAMUQ was doing well as an institution to support and encourage its female students, the number one thing that participants mentioned was that females outnumbered males at the institution. Having so many female peers provides support and encourages participants. They also discussed how they felt most of their professors are balanced in terms of encouraging both male and female participation in class, and that they have a chapter of the Society of Women Engineers (SWE) at TAMUQ.

### 3.3 Challenges at TAMUQ

Although participants expressed high satisfaction with their overall experience at TAMUQ and did not regret their choice to study engineering, they brought up multiple institutional challenges including:

1. lack of physical spaces where [Qatari] females can feel comfortable
2. gender bias from both professors and male peers
3. fewer research opportunities and trainings for females
4. not enough interaction with alumnae
5. lack of participation and an agenda promoting advocacy of female students in the Society of Women Engineers organization

### 3.4 Cultural/Industry Challenges

Beyond just the setting of TAMUQ, the participants discussed many perceived cultural, societal, and industrial challenges that female engineers face in Qatar and the wider Gulf region. These included:

1. Companies not accepting female employees
2. Companies not sponsoring females to study engineering

3. Gender bias and disparity in the workplace
4. Cultural expectations about women

## 4 Discussion

Findings from the focus groups and surveys revealed numerous factors affecting female engineering students at TAMUQ. From the moment the participants chose to study engineering, they faced various socio-cultural constraints related to choosing a male-dominated field. Students indicated interest in the field and a need to “prove” something to their families as motivating factors behind their decision.

Due to the university’s demographics of almost 60% female students, it is important to understand some of the institutional strengths and weaknesses in terms of supporting female students. When asked about institutional successes in terms of the university supporting its female students, there were some positive views towards professors and students were overall satisfied with the university and their choice of studies. The primary success, however, seems to be the enrollment of a large number of female students contributing to an unofficial support system through female peers. In terms of challenges, participants indicated the lack of a women-only physical space and with that lost opportunities for networking, gender bias from both professors and male peers, less research opportunities and trainings for females, lack of support and mentorship, particularly in terms of female role models and interaction with alumnae, and the lack of participation and advocacy for women in the Society of Women Engineers as the main aspects affecting them within TAMUQ. These institutional challenges are compounded by industry-wide practices in Qatar that are detrimental for women engineers. Participants, in this respect, indicated perceptions of companies not accepting female employees and not sponsoring females to study engineering, a prevalence of gender bias and disparity, and cultural expectations affecting women in the workplace.

The fact that participants’ perceptions indicate considerably more challenges than successes can be examined in light of a prevailing culture of gender bias and sexism towards women. Similar to findings reported in Alhasani (2013), Aswad et al. (2011) and Fawwaz (2014), it is possible to see mentorship and support systems, cultural norms, and stereotyping as crucial factors affecting women engineers in the region. Internally, TAMUQ needs to ensure consistency and fairness across genders, in terms of the space, support, and opportunities it provides to its students. It needs to better prepare its female students to navigate those ‘invisible barriers’ (Qayyum, 2012) and have strategies to assert themselves in male-dominated work settings. At the same time, industry-wide challenges need to be addressed to ensure women can use the skills they have gained from their engineering degree. It is in this context that we want to provide a series of recommendations based on the experiences of our participants.

In both the focus groups and in meetings with our faculty-student research team, a number of recommendations were suggested. These included:

- Creating opportunities for more interaction, including informal conversations, with alumnae

- Offering workplace skill development for current female students and continuing education courses for professional female engineers/alumnae on topics such as bias, negotiation, etc.
- Inviting more women working in industry to give lectures and workshops – organizing a special lecture series focused on women in STEM
- Hiring more female professors so that students have more role models
- Liaising with industry to encourage equal sponsorship opportunities and more equal hiring and retention practices
- Encouraging greater participation in the Society of Women Engineers and conducting activities that go beyond just social events to advocate for women and promote awareness of challenges facing women in STEM fields
- Providing more opportunities for students to discuss gender bias
- Designating space for a women-only lounge with desks and sofas that encourage female students to feel comfortable staying on campus, and to have an opportunity to network, to collaborate, and complete school work
- Providing funding for faculty and students to conduct further research on issues facing women in engineering in Qatar (such as this present study) and develop viable solutions

## 5 Conclusion

Although this study is limited in scope, it helps shed light on challenges faced by female engineering students in a non-Western context, such as the perceived detrimental consequences of not having segregated space or particular attitudes about gender roles and marriage in Qatar. It also supports findings from previous studies about challenges that women in STEM face worldwide, such as stereotypes, gender bias, and lack of role models. We hope to conduct further research on the experiences of TAMUQ alumnae. We also hope to conduct research on a wider scale with more engineering programs in Qatar and across the region.

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## References

al-Wazir, Y.: Arab Women in science – where are they heading? Al Arabiya, 13 February 2016. http://english.alarabiya.net/en/views/news/middle-east/2016/02/13/The-lost-Arab-women-in-science.html. Accessed 19 Jan 2017

Alhasani, N. M.: WiSE Women of the UAE Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia, June 2013. https://peer.asee.org/22759

Aswad, N.G., Vidican, G., Samulewicz, D.: Creating a knowledge-based economy in the United Arab Emirates: realising the unfulfilled potential of women in the science, technology and engineering fields. Eur. J. Eng. Educ. **36**(6), 559–570 (2011)

Baytiyeh, H.: Are women engineers in Lebanon prepared for the challenges of an engineering profession? Eur. J. Eng. Educ. **38**(4), 394–407 (2013)

Durrani, A.: More Arab women studying STEM. U.S. News, 04 March 2015. http://www.usnews.com/education/best-arab-region-universities/articles/2015/03/04/more-arab-women-studying-stem. Accessed 20 Jan 2017

Fawwaz, L.N.: Women in STEM: The UAE experience. United Nations Commission on the Status of Women (United Nations) (2014)

Goldberg, D.E., Somerville, M.: A Whole New Engineer: The Coming Revolution in Engineering Education. Threejoy Associates Inc., Douglas (2014)

Hill, C., Corbett, C., St Rose, A.: Why so Few? Women in Science, Technology, Engineering, and Mathematics. American Association of University Women, Washington, D.C. (2010)

Hillman, S., Salama, G., Ocampo Eibenschutz, E., Awadh, S., El-Said, L.: Being a female and an engineering student in Qatar: successes, recommendations, and challenges. In: 2017 American Society for Engineering Education. ASEE Annual Conference & Exposition Proceedings, 25–28 June Columbus, Ohio (2017)

Hopkins, N.: MIT and gender bias: Following up on victory. Chronicle High. Educ. **45**(40), B4–B5 (1999)

Iversen, E.: Arab women make a charge into engineering. Start Engineering, 06 October 2016. http://start-engineering.com/start-engineering-now/2016/10/6/arab-women-make-a-charge-into-engineering. Accessed 19 Jan 2017

Kantor, J.: To grow their participation In STEM, women need to come together. Entrepreneur Middle East. 30 August 2016. https://www.entrepreneur.com/article/281567. Accessed 20 Jan 2017

Mannan, M.: Middle East female STEM graduates turning their backs on the sector. 7 Days UAE. 04 May 2016. https://7days.ae/middle-east-female-stem-graduates-turning-backs-sector. Accessed 19 Jan 2017

Margheri, L.: Women in engineering, science, and technology in the United Arab Emirates. IEEE Robot. Autom. Mag. **23**(2), 102–104 (2016)

McCullough, L.: Women's leadership in science, technology, engineering and mathematics: barriers to participation. In: Forum on Public Policy Online (2011)

Mitchell, J.S., Paschyn, C., Mir S., Pike K., Kane, T.: In Majaalis Al-Hareem: the complex professional and personal choices of Qatari women. DIFI Family Research and Proceedings, p. 4 (2015)

Moss-Racusin, C.A., Molenda, A.K., Cramer, C.R.: Can evidence impact attitudes? Public reactions to evidence of gender bias in STEM fields. Psychol. Women Q. **39**(2), 194–209 (2015)

Moss-Racusin, C.A., Dovidio, J.F., Brescoll, V.L., Graham, M.J., Handelsman, J.: Science faculty's subtle gender biases favor male students. Proc. Natl. Acad. Sci. **109**(41), 16474–16479 (2012)

Nnachi, N.O., Okpube, M.N.: Psycho-Social determinants of gender prejudice in science, technology, engineering and mathematics. J. Educ. Pract. **6**(17), 190–194 (2015)

Qayyum, M.: Women in Middle East/North Africa are underrepresented in science and technology professions. Huffington Post, 29 May 2012. http://www.huffingtonpost.com/mehrunisa-qayyum/women-middle-east-technology_b_1553440.html

Robnett, R.D.: Gender bias in STEM fields variation in prevalence and links to STEM self-concept. Psychol. Women Q. **40**(1), 65–79 (2015)

Sheltzer, J.M., Smith, J.C.: Elite male faculty in the life sciences employ fewer women. Proc. Natl. Acad. Sci. **111**(28), 10107–10112 (2014)

Sulaiman, N.F., AlMuftah, H.: A Qatari perspective on women in the engineering pipeline: an exploratory study. Eur. J. Eng. Educ. **35**(5), 507–517 (2015)

Texas A&M University at Qatar: Texas A&M at Qatar, QBWA to partner to support women engineers and engineering students, 27 May 2015. http://www.qatar.tamu.edu/news-and-events/news/Texas-A-M-at-Qatar-QBWA-to-partner-to-support-women-engineers-and-engineering-students. Accessed 23 Jan 2017

UNESCO: Improving access to engineering careers for women in Africa and in the Arab States. UNESCO, 10 December 2013. http://www.unesco.org/new/en/natural-sciences/science-technology/engineering/infocus-engineering/women-and-engineering-in-africa-and-in-the-arab-states/. Accessed 20 Jan 2017

Williams, J.C.: The 5 biases pushing women out of STEM. In: Harvard Business Review (2015)

# Professors' Competences Through the Perspective of STEM Students

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**Abstract.** Tertiary education institutions educate a great number of individuals of all ages every year with the aim to assist them in developing a set of skills, knowledge, competences and attitudes. The overall aim of the education process is dual: employment and contribution to society. Actors with a direct impact in this process are the professors, teachers with various roles, lecturers or heads of laboratories, supervisors or examiners.

While teachers in all levels of formal education are trained in specialised institutions and acquire formal teaching qualification, higher education professors lack such education in most cases. Consequently, the question raised is what competences a university professor should have in order to reach a quality teaching practice. In modern times, these competences are not limited to teaching, since professors perform multiple roles. Interpersonal competences, designing and implementing the learning process as well as innovation are also in demand.

This study will reflect how students in European STEM education perceive professors' competences within the given framework, based on their university, field of study and degree. The conclusion is reached on which competences are of more importance and which should be reinforced in order to improve the quality of transmitting the knowledge in higher educational institutions.

**Keywords:** STEM · Professor competences · Student perception

## 1 Introduction

Tertiary education institutions educate a great number of individuals of all ages every year with the aim to assist them in developing a set of skills, knowledge, competences and attitudes. The overall aim of the education process is dual: employment and contribution to society. Actors with a direct impact in this process are professors, teachers with various roles, lecturers or heads of laboratories, supervisors or examiners. While teachers in all levels of formal education are trained in specialised institutions and acquire formal teaching qualification, higher education professors lack such education


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in most cases [1–3]. Consequently, the question raised is what competences a university professor should have in order to reach a quality teaching practice. Therefore, the present study constitutes an attempt to determine which competences are considered most important by students, for university professors to have. Special attention is given to the stakeholders most influenced by the teaching process in higher education institutions because they often detect problems that other stakeholders cannot see or choose to oversee [5].

In the European Higher Education Area (EHEA), a paradigm shift is occurring, moving from content-based to competence-based learning [6–8]. The introduction of "new" qualifications deriving from professional competences [9] overrides the traditional university professors' role, which is solely based on subject matters and disciplines. On the contrary, it sets the locus on functional learning processes, that require the application of a set of knowledge, attitudes, skills, while involving the students in an active way. Aiming at developing skills for life, professors are not only expected to design and present the content of the course, but they are also responsible for providing incentives and reinforcing the critical thinking of their students [10]. Interpersonal competences, designing and implementing the learning process as well as innovation are also in demand, for professors to be able to perform this multifaceted role. Therefore, lecturer training based on competences may be the answer to the question how to achieve better results for the target group: students [4].

Educational Involvement is one of the main activities that BEST (Board of European Students of Technology) offers to STEM students all over Europe. It creates a platform to raise students' awareness on educational matters and to provide stakeholders of the European STEM Education with the students' genuine input. Through Events on Education (EoEs) and an international survey, opinions on the desired competences of university professors were gathered, leading to the development of a more specific research. Offering a framework with competences to students, their opinion was sought through a survey on how important each one is and to what degree, with further aim to select the most vital professors' competences according to them.

## 2 Competences

In recent decades and especially in Europe, a growing attention on competences is detected. Introduced to mainly describe what earlier was mentioned as qualifications, competences have gradually acquired a major role in defining many professions, including university professors.

Introduced in the scientific discourse by White [14], the term competence aims to describe performance motivation, while it was approached as an effective interaction between the individual and his environment. However, the vanguard of competence-performance approach was Chomsky [15], defining linguistic competence as individual's innate ability to acquire the native language. Therefore, he distinguishes competence from performance. Later on, management introduced action competence, which refers to "intellectual abilities, content-specific knowledge, cognitive skills, domain-specific strategies, routines and sub-routines, motivational tendencies, volitional control systems, personal value orientations, and social behaviours" (Boyatzis as cited in [12]). By including competences related to specific professions, the focus moved to conditions related to specific roles, which ensure success in specific social groups [12].

Whereas Walker (as cited in Shukla [16]) defines competence as a set of "attributes (knowledge, skills and attitudes) which enable an individual or group to perform a role or set of tasks to an appropriate level or grade of quality or achievement (i.e. an appropriate standard) and thus makes the individual or group competent in that role", Gonzales and Wagenaar [13] describe it as "a dynamic combination of cognitive and metacognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values" emphasizing its complicated nature and correlating it to professionalism. Kunter et al. [11] move a step forward suggesting the term professional competence while referring to higher education professors' competences in their attempt to relate it to teaching success. While competences can be approached as "the skills, knowledge, attitudes, and motivational variables that form the basis for mastery of specific situations" [11], they are not innate but learnable. In that sense, professional competence is the implementation of the above-mentioned set of abilities into practice, especially with reference to highly complicated and demanding professions that involve multiple roles, like that of professors.

## 3 Methodology

Events on Education (EoEs) were created by BEST aiming to raise awareness and involve students in the process of education improvement. EoEs are bringing together students, professors and company representatives in order to discuss relevant educational topics. To obtain diverse results, more than 20 STEM students from different countries, cultural and educational backgrounds, participate in each event. Their gender, year of study, study field and origin are among the factors that are taken into account to ensure the diversity of the participants and therefore reach a broader understanding of the given topics. Surveys are often used by BEST in order to collect information from a selected group of students. The surveys address students from the universities where a Local BEST Group (LBG) is present.

The findings of this study derive from a survey conducted in a few selected universities from the BEST network within a time frame of around 4 weeks (April 2017). After an application process, 11 LBGs were selected to participate in the study. The selection was made taking into consideration the variety of countries and accessibility to students. In Fig. 1 the distribution of responses per country, where the students' attend university, is shown. Universities that took part in the survey are KU Leuven - Belgium, University of Lorraine - France, Friedrich-Alexander-University Erlangen-Nuremberg - Germany, National Technical University of Athens - Greece, Politecnico di Milano - Italy, Delft University of Technology - Netherlands, Silesian University of Technology - Poland, University of Aveiro - Portugal, Politehnica University of Bucharest - Romania, University of Ljubljana - Slovenia and National Technical University of Ukraine "Kyiv Polytechnic Institute" - Ukraine, as indicated in Fig. 2. A total of 323 responses were gathered, out of which 318 valid responses were taken into account for the analysis of the survey.

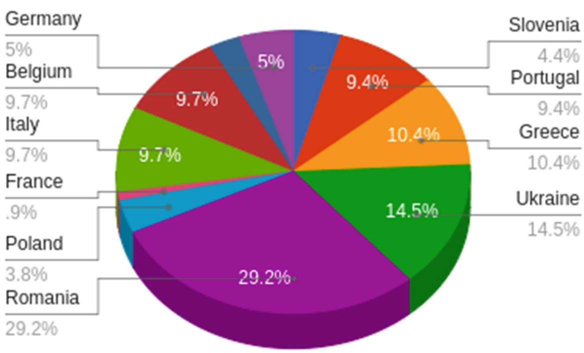


**Fig. 1.** Graph of the survey responses by country

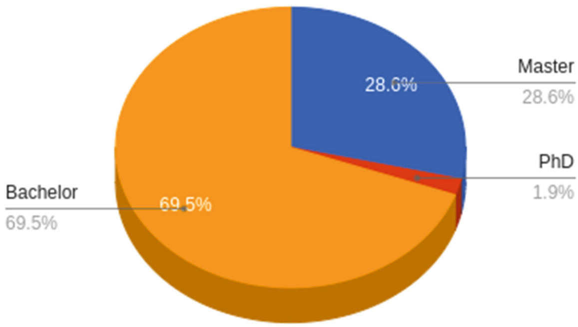


**Fig. 2.** Graph of responses per cycle of degree

Responses were gathered from students enrolled in Bachelor, Master and PhD programmes in the chosen Universities, whereas the majority of responses are from Bachelor students, as indicated by Fig. 2.

Considering the gender of the participants, 62,9% declared themselves as male, while 35,2% as female. 1,9% of participants preferred not to declare their gender.

For the content of the survey, the framework developed by Lopez & Perez-Poch was used [4]. The framework gives a list of 49 indicators on competences required for good teaching practice divided into six areas: interpersonal, methodological, communicative, planning and management, teamwork and innovation competences. Apart from the given indicators, one open question per area was added to gather additional input on competences that were not covered but were still considered relevant by students (e.g. "Other interpersonal competence indicators that you find important and that is not covered above:") [17]. All areas with indicators are described in Appendix 1 and Appendix 2 [4].

## 4 Results

In the original study, the main focus is on the professors' competences and their indicators which were perceived most poorly by the professors. When analysing the students' opinions, the indicators ranked as more important should be reinforced by the professors. The indicators were rated using a Likert scale where the choices were the following: "not important" (1); "somewhat important" (2); "important" (3); or "very important" (4). Indicators ranked as "important" (3) or "very important" (4) by more than 75% of the students, are considered as being of high importance to the sample.

In Fig. 3, the results are obtained according to the following steps: the percentage of both "important" (3) and "very important" (4) rankings per indicator is summed. After which, the average of these sums is considered as the average of importance to which the indicators belong. According to the results, the innovation and interpersonal competences are given a high importance ranking according to more than 75% of the surveyed students. In comparison, the teamwork competences seem to have the relatively lowest importance according to students, even though this percentage is higher than 65%.

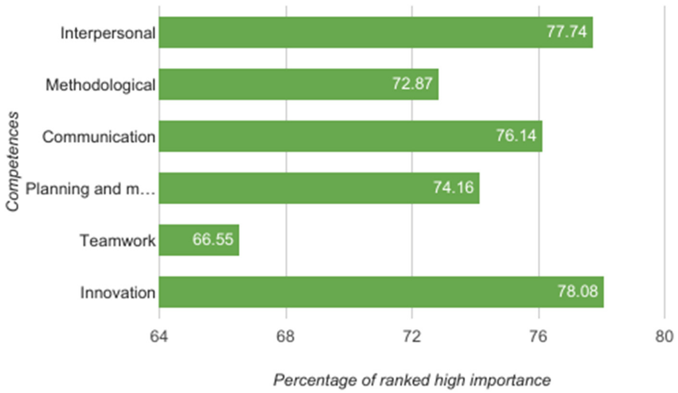


**Fig. 3.** Importance ranking of the professors' competences, summed percentage of "important" (3) and "very important" ranking, represented per competence

In Table 1, the indicators, according to the students' perception of their importance, are clustered within a few ranges. As mentioned before, an indicator or a competence is considered to have a high importance when the percentage is higher than 75%. Thus, the indicators that belong to the categories 75–80%; 80–90% and 90–100% are acknowledged as such.

**Table 1.** Importance ranking of the professors' competences - Summed importance of each indicator clustered within the range of importance

| | | | | | | |
|---|---|---|---|---|---|---|
| 0–60% | | MC10 | CC8 | | | |
| 60–70% | IC6 | MC4; MC5; MC8 | CC6; CC7 | PMC4; PMC5 | TC2; TC7 | |
| 70–75% | IC3; IC7 | | CC5 | | TC1; TC5; TC6 | InnC3; InnC4; InnC6 |
| 75–80% | IC1; IC5; IC8 | MC1; MC2; MC3; MC6; MC7; MC9; MC11 | CC1; CC4 | PMC1; PMC2; PMC3 | TC3; TC4 | InnC5; InnC7 |
| 80–90% | IC2; IC4; IC9 | | CC3; CC9 | PMC6 | | InnC1; InnC2 |
| 90–100% | | | CC2 | | | |

Using the same principle as for Fig. 3, summed importance of each indicator was calculated and presented in Table 2. Highest importance among interpersonal competences was given to the indicator "IC9: Encourage motivation". For methodological competences, highest importance was given to the indicator "MC1: Use methodological strategies that stimulate student participation". Considering communication

**Table 2.** Importance ranking of the professors' competences - Summed importance of each indicator

| Indicator | Summed importance | Indicator | Summed importance | Indicator | Summed importance |
|---|---|---|---|---|---|
| IC1 | 76.73 | MC1 | 79.87 | CC1 | 79.87 |
| IC2 | 88.99 | MC2 | 75.47 | CC2 | 90.88 |
| IC3 | 74.84 | MC3 | 75.47 | CC3 | 88.68 |
| IC4 | 81.76 | MC4 | 68.55 | CC4 | 78.62 |
| IC5 | 77.99 | MC5 | 66.98 | CC5 | 70.75 |
| IC6 | 61.64 | MC6 | 79.87 | CC6 | 67.30 |
| IC7 | 70.44 | MC7 | 79.56 | CC7 | 66.67 |
| IC8 | 77.36 | MC8 | 68.24 | CC8 | 57.55 |
| IC9 | 89.94 | MC9 | 76.10 | CC9 | 84.91 |
| TC1 | 71.38 | MC10 | 53.46 | InnC1 | 86.48 |
| TC2 | 63.52 | MC11 | 77.99 | InnC2 | 83.65 |
| TC3 | 75.47 | PMC1 | 79.87 | InnC3 | 73.90 |
| TC4 | 76.42 | PMC2 | 75.79 | InnC4 | 74.84 |
| TC5 | 74.84 | PMC3 | 76.73 | InnC5 | 77.67 |
| TC6 | 72.96 | PMC4 | 64.47 | InnC6 | 71.38 |
| TC7 | 67.61 | PMC5 | 66.04 | InnC7 | 78.62 |
| | | PMC6 | 82.08 | | |

competences, planning and management competences, teamwork competences and innovation competences, highest importance was given to indicators "CC2: Explain with clarity and enthusiasm", "PMC6: Assess implementation of the program regarding learning and acquisition of competences; detect weaknesses and introduce improvements to ensure achievement of outcomes", "TC4: Act for the good of the team" and "InnC1: Analyze the teaching/learning context to identify areas for improvement and apply innovative strategies and/or resources, respectively". The indicator with indicator with highest priority of all was "CC2: Explain with clarity and enthusiasm", with 90.88% of importance.

Out of all the indicators of the six different competences, only two did not receive a ranking of importance of more than 60% of the students. The two lowest ranked indicators were: "MC10: Use different formative assessment strategies" and "CC8: Use body language as appropriate". The first aforementioned indicator has a complex wording and it is possible that students may not have understood its meaning. The second lower ranked indicator shows that around 40% of the surveyed students do not see body language as an important criterion when evaluating a professor's teaching practice.

In comparison with summed importance of each indicator, only two indicators were marked as "very important" for more than 60% of applicants and these are "IC9: Encourage motivation" with 62.58% and "CC2: Explain with clarity and enthusiasm" with 61.32%. Indicators that were marked as "very important" for more than 50% of applicants are "IC2: Develop reflexive and critical thinking" with 54.40% and "CC3: Use definitions, examples and alternative explanations to facilitate understanding of the topic" with 53.14%. Surprisingly, indicator "CC8: Use body language as appropriate" has the highest percentage of being "not important", even 10.69%.

From Table 3, differences in the importance between students and professors can be clearly observed. The most notable difference is in terms of the innovation competences of professors, ranked 1st by the students and 5th by professors. This competence focuses on a professor's constant improvement of the teaching-learning processes. This also implies that professors should be proactive when it comes to education innovations.

**Table 3.** Comparison of the importance of the professors' competences according to students' and professors' perceptions (the data on the professors is taken from reference [4])

| Ranking of importance | Students | Professors (all UPC) | Professors (non-UPC) |
|---|---|---|---|
| 1 | InnC (78.08) | CC (97.42) | CC (98.26) |
| 2 | IC (77.74) | IC (96.43) | MC (96.96) |
| 3 | CC (76.14) | MC (95.23) | IC (96.79) |
| 4 | PMC (74.16) | PMC (94.45) | PMC (95.39) |
| 5 | MC (72.87) | InnC (88.29) | InnC (89.95) |
| 6 | TC (66.55) | TC (84.92) | TC (89.95) |
| *Sample size (n)* | *318* | *503* | *1,884* |

According to the results, both students and professors perceive teamwork competences of professors as the least important. This competence refers to the lecturer not as a leader of the group but rather as a team member and equal to the students. One conclusion which can be drawn is that students still wish to see their professors as leaders who will guide them through the learning process.

Figures 4 and 5 represent the correlation between the students' and the professors' (from UPC and non-UPC) perception on competences respectively. The Pearson's correlation coefficient in the first case is 0.57 and in the second 0.5.

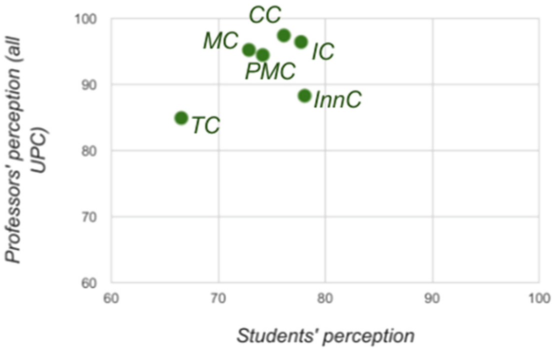


**Fig. 4.** Students' and professors' (all UPC) perception of the professors' importance of each competence

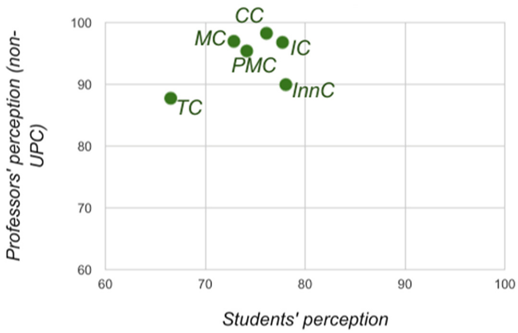


**Fig. 5.** Students' and professors' (non-UPC) perception of the importance of each competences

## 5 Discussion

During various EoEs, the topic of the professors' competences was often mentioned, and several competences were recurring as the most desirable ones from students' perspective. These competences reflect teaching skills, professors' attitude, relation and interaction with students, encouraging motivation and empathy, integration of technology in lectures, using innovative teaching methods, etc. [6–8]. Comparing opinions gathered through EoEs with the larger sample from the results of the survey, it is shown they are mostly compatible.

Professors' classroom behaviour and lack of lecturing skills have a major negative impact on students' motivation [6]. Miscommunication with students and lack of empathy result in students perceiving their professors as under-skilled and less interesting, leading to a loss of motivation during their lectures and therefore for the course in general [6, 7]. Analysing the importance of each indicator, developing reflexive and critical thinking (IC2) has shown to be of high importance for 54.40% of applicants, encouraging motivation (IC9) for 62.58%, creating a climate of empathy (IC5) for 43.71%, showing tolerance toward other points of view (IC4) for 40.57% and planning practical activities that encourage self-learning and the development of personal and professional skills (MC6) for 44.03%. Comparing it with the summed importance of each indicator from Table 2, importance is even higher, with 88.99%, 89.94%, 77.99%, 81.76% and 79.87% respectively. “MC1: Use methodological strategies that stimulate student participation” has a high percentage of summed importance in the responses, with a total of 79.87%.

The need for professors to keep up with the latest updates in their field and being more keen to integrate technology in their lectures was raised [6–8]. Yet, the survey shows these indicators are not considered as important, with only 39.94% of applicants rating it as very important (MC9). However, when counting the summed importance, that number is significantly higher - 76.10%.

Taking professional critics objectively, creating the atmosphere where students can freely express their opinions on the subject, the teaching or the learning process is highly valuable in students’ eyes [7]. Providing continuous feedback to stimulate students’ learning and autonomy (MC11) is highly important for 41.19% of applicants. Creating spaces where students can freely express their opinion on the subject, the teaching or learning process, gather this information and provide a response (CC5) is not ranked very high on the importance scale, only 35.85% of applicants recognised it as very important. Using the summed importance, both percentages increase to 77.99% and 70.75% respectively.

The ability to set and transmit the goals of their lectures with clarity and enthusiasm are recognised as characteristics of a good professor [7]. Results from the survey are aligned with it, “CC2: Explain with clarity and enthusiasm” has 61.32% of importance and “CC3: Use definitions, examples and alternative explanations to facilitate understanding of the topic” has 53.14%. The summed importance of CC2 is 90.88% and of CC3 is 88.68%.

Indicators that are also recognised as very important, with a percentage of summed importance over 75% are “PMC6: Assess implementation of the program regarding learning and acquisition of competences; detect weaknesses and introduce improvements to ensure achievement of outcomes” with 82.08%, “TC4: Act for the good of the team” with 76.41% and “InnC1: Analyze the teaching/learning context to identify areas for improvement and apply innovative strategies and/or resources” with 86.48%.

## 6 Conclusion

This research has shown how professors’ competences are perceived by students in European STEM education. The results of the survey were analysed and later compared with input that was gathered through EoEs. The aim was to conclude which competences are of more importance and should therefore be reinforced in order to improve the quality of the knowledge transfer in higher education institutions.

This study identified several competences and their indicators, which were acknowledged as highly important both among EoE participants and participants in the survey. Results from the survey show that students highly ranked the ability of professors to "CC2: Explain with clarity and enthusiasm", "PMC6: Assess implementation of the program regarding learning and acquisition of competences; detect weaknesses and introduce improvements to ensure achievement of outcomes", "TC4: Act for the good of the team" and "InnC1: Analyze the teaching/learning context to identify areas of improvement and apply innovative strategies and/or resources, respectively". Indicators that students value the least are "MC10: Use different formative assessment strategies" and "CC8: Use body language as appropriate". Regarding the competences, innovation and interpersonal competences are recognised as most important.

When compared with professors' perspective, the differences in perceiving the importance between students and professors can be clearly observed. The most distinguished one refers to professors' innovation competences, ranked 1st by the students and 5th by professors. According to the results, both students and professors perceive teamwork competences of professors as the least important.

The present study reveals the preference of students towards a group of competences that the ideal professor should develop, while it also points out a group of competences not in demand. Investigating further why the competences ranked highly as important are identified this way by the students, through realising focus group discussions in future EoEs, can extend and explain the findings of this survey. The aim of such an action would be to understand how students perceive the learning process, what they expect from it and how it can be improved.

## References

1. Postareff, L., Lyndblom-Ylanne, S., Nevgi, A.: The effect of pedagogical training on teaching in higher education. Teach. Teacher Educ. **23**(5), 557–571 (2006)
2. Brownell, S., Tanner, K.: Barriers to faculty pedagogical change: lack of training, time, incentives, and… tensions with professional identity? CBE—Life Sci. Educ. **11**, 339–346 (2012)
3. Gougoulakis, P.: Educating scientists philosophy and practice of University Pedagogy. Academia **2017**(8), 35–75 (2017)
4. Lopez, D., Perez-Poch, A.: Detecting which teaching competences should be reinforced in an engineering lecturer training program. In: 44-th SEFI Conference, 12–15 September 2016 (2016)
5. Mohan, A., Merle, D., Jackson, C., Lannin, J., Nair, S.: Professional skills in the engineering curriculum. IEEE Trans. Educ. **53**(4), 562–571 (2010)
6. BEST: Principles of Effective Teaching and Learning & Class and Course Organisation. BEST Event on Education (EoE Ankara) (2015). https://issuu.com/bestorg/docs/eoe_ankara_final_report
7. BEST: Teach me to Teach you. BEST Event on Education (EoE Copenhagen) (2016). https://issuu.com/bestorg/docs/eoe-copenhagen

8. BEST: Teaching with Technology. BEST Event on Education (EoE Bratislava) (2015).https://issuu.com/bestorg/docs/baco_bratislava
9. Carreras Barnés, J.: El concepto de competencia y el diseño de planes de estudio a partir de perfiles competenciales. Dos cuestiones que hay que aclarar en el marco de las EEES. In El Debate sobre las competencias a la enseñanza universitaria, pp. 8–25. ICE UB, Barcelona (2005)
10. Moreno-Murcia, J., Silveira Torregrosa, Y., Belando Pedreño, N.: Questionnaire evaluating teaching competencies in the university environment. evaluation of teaching competencies in the university. J. New Approaches Educ. Res. **4**(1), 54–61 (2015)
11. Kunter, M., Klusmann, U., Baumert, J., Richter, D., Voss, T., Hachfeld, A.: Professional competence of teachers: effects on instructional quality and student development. J. Educ. Psychol. **105**(3), 805–820 (2013)
12. Winterton, J., Delamare-Le Deist, F., Stringfellow, E.: Typology of knowledge, skills and competences. Office for Official Publications of the European Communities, Luxembourg (2006)
13. Gonzales, J., Wagenaar, R.: Tuning educational structures in europe: Final report Phase I. University of Duesto & University of Groningen. http://www.relint.deusto.es/TUNINGProject/doc_tuning_phase1.asp. Accessed 31 July 2011
14. White, R.W.: Motivation reconsidered: the concept of competence. Psychol. Rev. **66**, 297–333 (1959)
15. Chomsky, N.: Rules and representations. Behav. Brain Sci. **3**, 1–61 (1980)
16. Shukla, S.: Teaching competency, professional commitment and job satisfaction-a study of primary school teachers. IOSR J. Res. Method Educ. (IOSRJRME) **4**(3), 44–64 (2014)
17. BEST: Survey Report - Professors' Competences Through the Perspective of STEM Students (2017). https://issuu.com/bestorg/docs/stem-prof-competences-survey-report

# Training the Achievement-Oriented Engineers for the Global Business Environment

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**Abstract.** To meet the global labor market requirements and to be able to contribute to the economical development of the mother country a contemporary engineer should enlarge his/her general outlook and be socially and professionally mobile. In order to be ready to be employed by the international European companies, the students alongside with acquiring the specialized engineering competences have to be familiar with the common characteristics of the European markets, to be competent in cross-cultural professional and business communications and to share European values. The new original academic course "Psychology of Professional Success" aimed to contribute to the engineering students' participation in the International European projects was introduced to some engineering curriculums. Empiric study showed that the course as a part of a comprehensive system of educational measures to train global engineers is efficient and helpful.

**Keywords:** Psychology of professional success · Global engineer
Labor mobility

## 1 Introduction

Academic and labor mobility of a contemporary engineer is the key point for the professional fulfillment in the post-industrial globalized society. Therefore the leading engineering Universities put integration into the international educational environment as a priority in the developmental strategies [1]. In order to be ready to be employed by the international European companies, the students alongside with acquiring the specialized engineering competences have to be familiar with the common characteristics of the European markets, to be competent in cross-cultural professional and business communications and to share European values. Interprofessional and cross-cultural contacts become a daily routine of an ambitious contemporary engineer even before he graduates from a university. Alongside with their engineering major top students pay much attention to foreign languages and other communicative competences that may promote their professional mobility [2].

To develop the global mobility of the engineering university graduates ant to train them for the modern European market place the university needs to provide high level


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of professional knowledge, skills and competences, good language skills and a set of personal qualities, such as: willingness to change, sociability, collaborative skills, strive for self-improvement and life-long learning, stability of motivation and flexibility of behavioral strategies, open mind and some other personality characteristics. Altogether these characteristics form socio-psychological readiness of engineering students for academic mobility [3].

A set of pedagogical conditions for the effective formation of socio-psychological readiness for academic mobility of engineering students was introduced at the Kazan National Research Technological University.

An original academic course "Psychology of Professional Success" was methodologically developed and practically implemented as a component of the introduced system of educational conditions. The discipline aims at the development of the concept of success as a phenomenon. The purpose for the students is to acquire the practical skills to develop communicative and cross-cultural competence and other personality characteristics that favor professional fulfillment and success at the global market place. The course contributes to the engineering students' participation in the International European projects.

## 2 Approaches and Concept

Most employers put their demands in terms of the personnel's knowledge and 'modus operandi'. They pay attention to such traits as team working skills, readiness for life-long learning and self-development and problem solving. Thus the aim of professional educational is to develop professional competences and to teach a student to manage various socio-professional situations.

Thus training for academic mobility may be considered as an integrative comprehensive system that includes professional education (technological, project-oriented, administrative or managerial training depending on the professional specifics), learning of foreign languages and development of personal qualities, motives and skills that comprise socio-psychological readiness that plays an important role in the student's academic mobility [4].

The literature analysis revealed that socio-psychological readiness for the academic mobility of engineering students has the following structure [5]:

- Motivational component. Stable intrinsic motivation for academic mobility, readiness for solving challenging social, professional and academic situations;
- Cognitive component. Knowledge and information that form the basis of the socio-psychological readiness for the academic mobility.
- Personality performance component. Socio-psychological traits necessary for efficient performance and successful interaction of the future engineer in the mobility context.
- Communicative component. Sociability, team working skills, conflict management skills, friendliness and other communicational characteristics necessary for successful academic mobility.

The system of comprehensive development of the socio-psychological readiness for academic mobility developed at the Kazan National Research Technological University included the following pedagogical conditions:

1. Gradual development of the socio-psychological readiness for academic mobility in the educational process at the engineering university.
2. Development of engineering students' motivation for academic mobility, positive emotional attitude towards education and towards the chosen profession.
3. Actualization of Humanities' potential within the engineering majors to develop the skills of career planning, career development and activity in the future profession.
4. Personal development through learning was provided by formation of proper academic environment: students were engaged into extra-curriculum research work at their departments, participated in students conferences, published papers, issued student newspapers, made individual projects, etc.
5. Purposeful creation of educational situations to include students into social intercourse in the context of future engineering performance. The students made suggestions to improve the existing technological processes at enterprises [6].

Within the third condition a new training course "Psychology of Professional Success" was introduced, based on previously developed training course "Psychology of Success" to contribute for the training of the engineering students to the career in International European companies. Besides this condition was applied by Social Sciences and Humanities in the major engineering curricula and by the minor degree programs. Of course Social Sciences and Humanities are included into engineering curricula according to the Federal State Educational Standard of Higher Professional Education of Russian Federation, and were studied by all students both in the control and in the experimental groups. However experimental group students were motivated to enter minor degree program at the Faculty of Additional Professional Education. The following minor programs were introduced to them: "Psychology", "Education Science", "Industrial Economics", "Management", "Marketing" and "HR". All the above-mentioned programs comprise significant humanitarian component. Besides the experimental group students were taught the "Psychology of Professional Success" course as an elective.

## 3 Psychology of Professional Success

The new course "Psychology of Professional Success" aimed to the formation of the engineering Universities students' availability for the participation in International European projects.

The key idea of the new course is as follows: "from personal success to professional fulfillment". This idea determined the peculiarities of the course syllabus. It includes two parts: (a) personality characteristics that provide the basis for successful behavior and (b) psychology of professional fulfillment.

The course touches upon the following main topics: interpersonal and cross-cultural communication, multicultural variety, academic mobility, leadership, decision-making, psychology of success, and project management. Students will master the art of effective communication, the fundamentals of goal settings and time-management, the art of presentation, conflict management, and the general principles of the successful professional career planning.

One of the course tasks is to study the cultures, economical systems, mentalities and history of European countries. In addition to that, the course is aimed to give some necessary knowledge in the field of sociolinguistics, culture-oriented linguistics, and cross-cultural psychology.

The course is taught during one semester and consists of 72 academic hours. The main units of the discipline is as follows:

1. The psychological and sociological fundamentals of professional success.
2. Styles of individual behavior. Personal traits as determinants of professional success.
3. Communication of global engineer. Communicational strategies. Cross-cultural communication.
5. Business and professional communication. Peculiarities of career building in European countries.
6. Sociolinguistics.
7. Linguistic and cultural studies.
8. Time management.
9. Conflict resolution and decision-making.
10. The history of European countries.

The course "Psychology of Professional Success" is apparently practically oriented. In addition to the theoretical information, each lecture includes elements of discussions and case studies. Seminars and workshops are projected with the use of modern interactive technologies and active educational methods, including different trainings, business role-playing games, video-interview and meetings with professionally successful people. The course ends with the final test to examine the students' readiness for the professional activity at the international European companies.

The course was developed using the following methodological principles: project based learning, learner centered or self-directed learning. The course offers a toolbox to address the major dimensions of the global teams where cultural differences might impact team performance. The tools in this toolbox deal with communications (verbal and physical), time management, leadership styles and conflict management. In each of these areas, a variety of techniques are used including flipped classroom, role playing, video recordings of situations, and self-reflective surveys on personality, leadership and conflict resolution, mind-mapping, etc. Students watch video interviews with high achiever in engineering and management, get to know their stories of success. Students practice teamwork as they make a project throughout the course to draw focus on the tools in the toolbox. To increase the students' awareness and knowledge about the cultures, events and current issues facing the European Union the students are required to search out non-Russian sources of information and to make searches in English and other European languages.

## 4 Empiric Study

The discipline "Psychology of Professional Success" received favorable reviews from the students. They mentioned its current significance in their academic and future professional performance as well as in their personal lives.

The experiment was carried out in 2010–2015. The population of the study consisted of students of the Institute of Chemical Engineering and Technologies of the Kazan National Research Technological University (KNRTU) majoring in "Material science and materials engineering" and "Chemistry and technology of energy-saturated materials and articles". Some of them also studied at the Faculty of Additional Education of KNRTU where they took minor degrees in one of the following additional programs: "Psychology", "Educational Science", "Company Economics", "Management", "Marketing" or "Human Resource Management".

The sample group included 86 students: control group (40 students) and experimental group (46 students). The model and pedagogical conditions for SPRAM development were systemically implemented at the experimental group while the control group took professional traditional training.

Empiric evidence was received that the course contributes to the development of the socio-psychological readiness for academic mobility. The results of the educational experiment showed that 36,9% of the experimental group students have productive (high) level and 52,2% of them had average level of the socio-psychological readiness for academic mobility.

The course was a part of a set of pedagogical conditions that were introduced to the engineering training process to develop the socio-psychological readiness for academic mobility. As a result the number of students with the productive level of the socio-psychological readiness for academic mobility increased 15,2%, and average level increased 17,4%. In other words, 32,6% of the experimental group student considerably improved their socio-psychological readiness for academic mobility whereas the control group showed almost the same level at the beginning and at the end of the experiment.

As a result of introducing all the suggested pedagogical conditions for development of the socio-psychological readiness for the academic mobility every component of the studied phenomenon significantly increased in the experimental group in comparison with the control group were the elaborated pedagogical conditions were not implemented (Table 1).

**Table 1.** Levels of socio-psychological rediness for the academic mobility components development in the Control (CG) and Experimental (EG) Groups (%)

| SPRAM levels | SPRAM components | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Motivational | | Cognitive | | Personality performance | | Communicative | |
| | CG | EG | CG | EG | CG | EG | CG | EG |
| Critical | 27,5 | 8,7 | 42,5 | 13,0 | 35,0 | 13,0 | 35,0 | 8,8 |
| Average | 42,5 | 43,5 | 45,0 | 52,2 | 45,0 | 54,4 | 42,5 | 39,1 |
| Productive | 30,0 | 47,8 | 12,5 | 34,8 | 20,0 | 32,6 | 22,5 | 39,1 |

The findings presented in Table 1 allow concluding that it is appropriate and reasonable to implement the suggested pedagogical conditions in the professional engineering training to develop the future engineers' readiness for the academic mobility.

## 5 Conclusions

Within a comprehensive system of educational measures to prepare the engineering students for the career in the International European companies the training course "Psychology of Professional Success" will enlarge the social, personal and professional opportunities for the global career planning.

As a part of a goal-oriented comprehensive pedagogical model of training the achievement-oriented future engineers the course is an efficient tool to prepare the students for their professional career at the European and global marketplace.

The course was implemented in the engineering Master's programs and in the minor degree programs for the engineering students. The course may be introduced to various engineering curriculums if it is adapted and corrected according to the corresponding engineering majors.

## References

1. Ziyatdinova, J., Bezrukov, A., Sanger, P. A., Osipov, P.: Best practices of engineering education internationalization in a Russian Top-20 University. In: Paper Presented at 2016 ASEE International Forum, New Orleans, Louisiana, June 2016. https://peer.asee.org/27236
2. Ivanov, V., Miftakhova, N., Barabanova, S., Lefterova, O.: New components of educational path for a modern engineer. In: Proceedings of the International Conference on Interactive Collaborative Learning (ICL), 20–24 September 2015, Florence, Italy, pp. 184–187. Institute of Electrical and Electronics Engineers, Red Hook (2015).
3. Grandin, J.M., Hirleman, E.D.: Educating Engineers as Global Citizens: A Call for Action/A Report of the National Summit Meeting on the Globalization of Engineering Education (2009)
4. Nurutdinova, A., Perchatkina, V., Zinatullina, L., Galeeva, G.: Innovative teaching practice: traditional and alternative methods (challenges and implications). Int. J. Environ. Sci. Educ. **11**(10), 3807–3819 (2016)
5. Gorodetskaya, I.M., Shageeva, F.T., Khramov, V.Y.: Development of cross-cultural competence of engineering students as one of the key factors of academic and labor mobility. In: Proceedings of 2015 International Conference on Interactive Collaborative Learning, ICL 2015, pp. 141–145 (2015). https://doi.org/10.1109/ICL.2015.7318015/Source Scopus
6. Shageeva, F.T., Erova, D.R., Gorodetskaya, I.M., Prikhodko, L.V.: Socio-psychological readiness for academic mobility of engineering students. In: Proceedings of 2016 International Conference on Interactive Collaborative Learning, ICL 2016 (2016). Paper ID 1743/Source Scopus

# Factors Affecting Student Engagement in Online Collaborative Learning Courses

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**Abstract.** Student engagement is a crucial precondition for successful learning. However, the discussion of engagement in online learning contexts has been limited. Thus, the main objective of this paper is to contribute to the current understanding of what affects online students' engagement. The paper reports on a case study conducted in the context of Uganda. A focus group interview was carried out with 14 participants of online collaborative learning courses. I identified four categories of factors affecting online students' engagement: (1) the online course environment, (2) informal online groups established by students, (3) interactions with co-located peers, and (4) online group dynamics. Thus, one of the main factors contributing to student engagement was scaffolding from an experienced peer and support of co-located classmates. On the contrary, the main challenge was the use of the course learning management system (LMS). Access issues led to the establishment of informal online groups. While students were generally motivated by the collaborative nature of the course, they also experienced challenges in their online groups in terms of cohesiveness.

**Keywords:** Engagement · Computer-supported collaborative learning (CSCL) Learning management systems (LMS) · Community of practice (CoP) Mobile learning

## 1 Introduction

The concept of student engagement is interrelated with motivation, emotions and interest [1], and its roots are based on the general goal of improving learning [2]. Antecedents of engagement may be of both social and academic character, and are shaped by the opportunities for active participation, intellectual efforts and social relationships available in the learning environment [3]. The teacher is capable of manipulating a range of important aspects affecting student engagement, such as design of the task, students' autonomy, structure, and interactions among the teacher and peers [3].

While the measures of engagement are helpful in evaluating the quality of learning experience, they have been mostly limited to on-campus settings [4]. The shift to online forms of education have caused interest in discussing the concept of engagement in online contexts [4–7]. Although it has been demonstrated that online learning can


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increase engagement [4, 6], we need a better understanding of *what* it is that promotes engagement [4].

This paper focuses on a case of a group of students co-located at a university in Uganda, participating in an online collaborative learning course run by a university in Norway. The paper seeks to address the following research questions:

1. What factors were contributing to student engagement?
2. What factors were impeding student engagement?

The paper is structured as follows. First, related research on student engagement and computer-supported collaborative learning (CSCL) is briefly introduced. Then, research design is described, including the context, data collection and analysis. Finally, the results are presented, followed by the discussion of the practical implications.

## 2 Related Research

### 2.1 Student Engagement

Engagement in academic work implies psychological investment and effort towards acquiring and mastering knowledge and skills. To describe the different dimensions of the concept, Fredricks et al. [3] suggested a three-part typology of student engagement including *behavioral engagement* (i.e., participation in academic and social activities), *emotional engagement* (i.e., reactions to teachers, peers, and academic work), and *cognitive engagement* (i.e., investment and willingness to put effort in learning).

Distributed learning has the potential to increase students' motivation to learn as it provides opportunities not available in the traditional classroom setting. Moreover, it is flexible and adaptive [8]. Studies focusing on student engagement in online learning contexts conclude that technology offers possibilities for higher order thinking as there is a better opportunity to take time for reflection and analysis. Students find it engaging to collaborate with peers. Another positive factor is the autonomy that students receive to manage their own learning [4]. Dixson [7] suggests that various communication channels as well as higher degrees of interaction among students and instructors are key factors affecting student engagement in online courses positively.

On the other hand, it is a well-known fact that this form of learning requires much self-discipline from learners [8], and the motivational factors become crucial in affecting overall performance [9].

### 2.2 Computer-Supported Collaborative Learning

Computer-supported collaborative learning (CSCL) is defined as "engagements among teams of two to approximately five members using synchronous and/or asynchronous tools in ways that support an instructional goal, such as to produce a product, resolve a case study, discuss a video example of a sales engagement, solve assigned problems, or complete an instructional worksheet" [10, p. 283]. To enable inquiry learning, the tasks should be authentic and personally relevant [11]. Giving tasks that simply ask to "work together" or "discuss a case" may not prompt deep discussions as such tasks are too easy or unstructured, which leads to one or two members completing most of the task for the group, with other members not participating or providing shallow contributions [10].

Overall, collaborative learning has shown general potential to increase social presence and improve individual learning results; however, still not all research comparing learning alone to collaborative learning goes in line with that statement [10]. There are major challenges in collaborative learning as students often find it motivationally and cognitively challenging [12].

## 3 Research Design

### 3.1 Context and Data Collection

The context of the study is a one-year CSCL course run by a University in Norway. The participants taking the course were based at three collaborating universities (the University in Norway and two foreign universities in Uganda and Sri Lanka). The course employed collaborative learning methods, and students from the three universities were assigned in small multicultural groups. At the time of the data collection, two rounds of the course had been completed. The data were collected during a focus group interview with the Ugandan participants in May 2016 held at the university in Uganda. Fourteen people participated in the interview, and they were representing both cohorts of the course. Eight participants were female, and six were male. All participants were employees at the university in Uganda and took the course as a part of their post-graduate education.

The format of the interview was very similar to an open discussion, and lasted around 1,5 h. The interviewer provided several general guiding questions for the students to reflect upon. The discussion evolved mainly around the issues of using the course learning management system (LMS) and interactions with local and distance peers.

### 3.2 Data Analysis

The study employs an explorative approach. Qualitative content analysis technique was employed to analyze the data. Hsieh and Shannon [13, p. 1278] identify qualitative content analysis as “a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns”. The aim of this method is to obtain a condensed description of a phenomenon with the help of descriptive categories [14]. Relying only on quantitative methods may reduce the accuracy of analysis due to the lack of attention to the qualitative dimensions [15].

Qualitative content analysis can be carried out both deductively and inductively [14]. Hseih and Shannon [13] discuss a directed approach to content analysis (i.e., *deductive* content analysis), whose aim is to test or conceptually extend an existing theory. Then, the existing theory helps to narrow down the focus. The challenge in this case is that the researcher may manipulate the participants by asking theory-led questions; moreover, during the analysis the researcher may fail to recognize important contextual aspects of the phenomenon due to over-reliance on the theory [13]. *Inductive* content analysis is suitable for the cases where the phenomenon has not been studied previously, or if the current knowledge about it is fragmented [14]. In this case, researchers let the categories flow from the data. It is possible to get a rich understanding of a specific phenomenon with this approach [13]. In the same fashion, Strijbos et al. [17] argue that while the statistical evaluations in the qualitative approach require a theory-led hypothesis in advance, the aim of understanding a phenomenon requires little to no explicit expectations prior to the process of data analysis. The main aim of qualitative inquiry is to understand a phenomenon rather than draw generalizations [16]. One of the advantages of approaching the content analysis method inductively is that the researcher can learn from the participants without imposing predefined categories on them [13].

I have therefore employed the inductive qualitative content analysis approach and let the categories emerge as I worked with the interview transcripts.

## 4 Results

Having analyzed the interview transcripts, I have identified four key categories to group the factors promoting and impeding student engagement: (1) the online course environment, (2) informal online groups established by students, (3) interactions with co-located peers, and (4) online group dynamics. The overview is presented in Fig. 1.

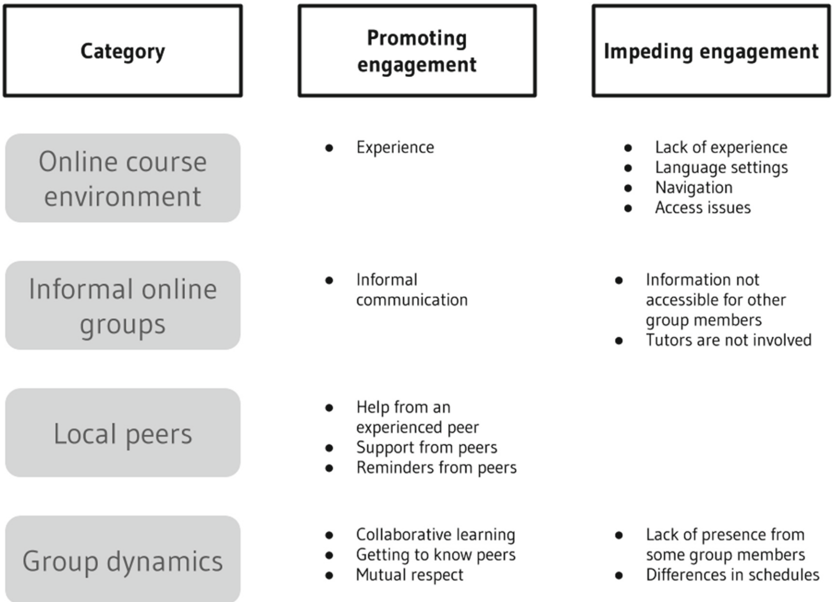


**Fig. 1.** Factors affecting online student engagement.

### 4.1 Online Course Environment

As the interview data demonstrate, there have been several issues related to the use of the LMS impeding student engagement. First of all, lack of experience resulted in students being insecure about using the system. Second, some of the students also experienced issues with language settings and navigation. Such technical problems may result in students feeling that they have lost control and autonomy over their learning, which affects their overall engagement [5]. Finally, the quality of connection often would complicate access to the LMS and course materials. Sometimes students could not connect, or could not load the necessary information. For example, although there were videos uploaded to the learning environment, students reported that it was not possible for them to load the videos. Moreover, the courses required constant access to the platform due to the collaborative nature of learning. As one of the respondents noted, her main challenge was to log in to the system every day. Having skipped one day, she failed to participate in an important group activity.

### 4.2 Informal Online Groups

The interview reveals that some groups chose to establish informal learning groups employing other communication channels that were more flexible in terms of access. Namely, WhatsApp was often mentioned. Small groups would often use this as a platform to discuss course materials synchronously.

In addition, being able to discuss informally was motivating for students and gave them confidence before contributing on the course platform. On the other hand, some of the students reflected that since the established informal groups only included the participants of a certain small group, other peers could not benefit from the discussions and information shared there. Similarly, the tutors could not follow and contribute to the informal discussions.

### 4.3 Support from Co-located Peers

The interview reveals that it was crucial for the newcomers to get support from the local peers (despite the availability of the facilitator and tutor online, students preferred to ask local peers for help). First of all, they relied on the knowledge and help of the more knowledgeable and experienced peer who had the ability to offer his guidance – especially in terms of the technology and software used in the course. It is a known fact that students need sufficient guidance on the features of the tool, as well as they need time to master the tool [18]. The more experienced peer's help was crucial in this case as students did not have the opportunity to receive direct instruction otherwise.

Moreover, several interviewees shared their stories about how the peer support helped them "stay onboard", not dropping out from the course due to lack of time for participation or complex life circumstances. The course instructor and online tutor were not aware of some of these students' engagement challenges. In addition, local peers would often "monitor" each other's participation and remind each other of important assignments and deadlines.

This evidence suggests that the peers managed to establish a close community of practice (CoP), with importance of the mentor and mutual support of its members. Such communities are emergent, and often they shape in the process of activity, unlike groups created to carry out a specific task [19], and they help people connect, share and support each other by sharing problems and experiences [20]. Knowledge here is treated contextually and it “re-sides” within certain practice. Thus, novices learn from experts [21].

### 4.4 Group Dynamics

The interview participants discussed that the collaborative learning mode was motivating in general. They were eager to learn about their peers. The interviewees emphasized that interactions on the platform were mutually respective, which contributed to their overall engagement. However, the interviewees also discussed that online groups were not always cohesive. Sometimes the whole group had to wait for one member to contribute in order to proceed with the activity. Some of the students experienced feeling left alone in the asynchronous environment when they did not receive a timely response. One of the reasons for decreased cohesiveness that was pointed out by the interviewees is the differences in work and study schedules of the course participants.

## 5 Discussion and Implications

The results of the interview suggest several practical implications which I discuss in this section.

### 5.1 The Role of Technology

The skills and knowledge to use the technology, as well as previous experience and attitudes affect users’ engagement with technologies [22]. In the learning context, familiarity with the online environment has been recognized as a major factor affecting engagement and participation patterns [23]. The degree to which the user believes the technology will help him perform well [24–26], how easy the user finds it to work with the technology [24, 26], and whether others think the user should use the technology [25–27] affect the intention to use the technology. At the same time, it is crucial to remember that cultural differences may influence on how the technology is perceived and used [28]. Therefore, *providing the newcomers with sufficient training on the use of the tools* is crucial for their further engagement in the learning process.

It is well-known that the choice of technological tools should be ideally matched with the affordance requirements of tasks [29]. In case of CSCL, it is crucial for students to be able to communicate effectively. Combination of both synchronous and asynchronous modes offers better opportunities for meaningful learning; and if some tools are not available in the environment, students may start searching for them themselves [30]. Integrating strengths of various communication tools is beneficial for coordination in the online environment [31] and creating a sense of community in online learning [32].

Ensuring social presence in online learning environments is an aspect that remains challenging [7], and more synchronous communication could address this aspect.

Moreover, *integration of mobile applications in the course design* could have been useful. Mobile learning has been growing in Africa; due to the lack of fixed-line infrastructure for information and communication technologies (ICT) in particular regions, the wireless infrastructure has been growing rapidly, leading to the exceptional rate of adoption of mobile technologies [33]. Of course, mobile learning as a whole has it challenges, including the diversity of platforms, unstable infrastructure in certain regions, different access for vulnerable and dominant groups, and different levels of digital literacy and experiences [34]. The interview data demonstrate that some of the students chose to switch to mobile applications that offered more effective and flexible access, which demonstrates the potential of the mobile applications in this context.

In addition, employing alternative communication channels offered students opportunities for informal discussion of the learning activities. However, this brings challenges. Monitoring and fairly assessing individual contributions in the process of CSCL is a complex issue [31]. In case of using social media, it is next to impossible to control the content posted in such groups, and how the groups are using the features of the technology [28]. Mobile learning, which usually happens outside formal educational settings, breaks the barriers between formal and informal learning [11]. Flexible learning implies that the resources and methods used by the participants of the learning process are highly distributed, varied and personalized both in terms of time and space [35]. Such activities are challenging to orchestrate and facilitate. I believe that the *tutors need access to the communication channels* students use for the discussion of their learning activities, as well as a structured approach of how they address the content posted there.

### 5.2 Social Aspects and Scaffolding Online Students

When engaging in complex, non-straightforward tasks members of the CoP realize the value of distributed expertise. There is no single solution to a problem, and negotiating with other members in the community is crucial to work things out. Especially tasks that allow the participants to relate to their own culture and context are likely to bring success. Complex tasks make the participants collaborate, divide labor and rely on each other for support [21].

The interview data demonstrate the potential of CoPs for supporting and engaging online learners. However, much is needed for the formation of effective communities of practice in such courses. It is not enough just to “design” the community online and expect it to work. Looi et al. [21, p. 502] formulated key principles for supporting and sustaining communities in our century: “foreground the practice, rely on existing social networks, build on strengths of membership diversity, construct task practices that require collaboration, and peer and leadership mentoring”. The role of mentors is crucial in CoPs. Mentoring can be loosely structured or, on the other hand, implemented in a way where a mentor carries out a specific role in setting up the activities [21]. I believe that *assigning a local tutor* in such a context is crucial.

It is also crucial to promote cohesiveness in collaborative learning groups. Earlier, it has been demonstrated empirically that participation patterns in online learning tend to emerge early in the process and remain consistent throughout the whole learning path [23]. Therefore, since the very beginning, it is crucial to help students develop certain metacognitive skills, i.e., procedural knowledge used for successful control of the learning behavior [36], such as goal setting, help seeking, time management, and self-monitoring. These skills are not directly accessible and are not easy to measure [36, 37]. Monitoring and addressing students' uncertainties may lead to improved cognitive and metacognitive abilities [38]. Providing feedback on all stages is important, as a wrong step early in the process of problem-solving may significantly impact the whole further process [10].

However, despite multiple attempts to classify the types of teacher interventions, it is a challenge to decide whether an intervention is necessary or not when a group of students are working autonomously [39]. When considering the multicultural learning context it is also important to remember that in particular learning contexts students may require more direct assistance from their instructors [40]. Therefore, it is important for the *online tutor to be monitoring students' discussions on the daily basis and addressing their inquiries*. There is still much to be understood about how to scaffold development of students' metacognitive skills and ensure group cohesiveness; one of the promising potential solutions here is the *implementation of collaboration scripts*.

## 6 Concluding Remarks and Future Research Directions

Better understanding of what affects student engagement in online contexts is crucial for ensuring effective online learning. While online learning provides students with multiple opportunities, it also imposes certain challenges and requires advanced metacognitive skills and self-discipline. I identified four categories of factors affecting online students' engagement: (1) the online course environment, (2) informal online groups established by students, (3) interactions with co-located peers, and (4) online group dynamics. From the practical point of view, the results of this paper demonstrate that learners need to be trained on the software to be used in the course. It also suggests that mobile applications have the potential to provide more flexible opportunities for student discussions. It is therefore beneficial to introduce them in the course design. However, it is important that tutors have an overview of the alternative communication channels utilized by students. Assigning a local tutor would contribute to the formation of CoPs, and thus support learners both cognitively and motivationally. Moreover, since some of the students may experience challenges due to the lack of group cohesiveness, it is important to provide them with adequate support, by means of online tutoring and/or collaboration scripting.

Further research should explore the principles of effective formation and scaffolding of CoPs locally and, especially, virtually. The level and quality of instruction that needs to be provided in online contexts remains an open question [8], and more research needs to be done into ensuring sufficient and effective scaffolding for online learners.

## References


1. Järvelä, S., Renninger, K.A.: Designing for learning: engagement, interest, and motivation. In: Sawyer, K. (ed.) The Cambridge Handbook of the Learning Sciences, 2nd edn. (2014)
2. Reschly, A.L., Christenson, S.L.: Jingle, jangle, and conceptual haziness: evolution and future directions of the engagement construct. In: Christenson, S.L., Reschly, A.L., Wylie, C. (eds.) Handbook of Research on Student Engagement, pp. 3–19. Springer, New York (2012)
3. Fredricks, J.A., Blumenfeld, P.C., Paris, A.H.: School engagement: potential of the concept, state of the evidence. Rev. Educ. Res. **74**(1), 59–109 (2004)
4. Robinson, C.C., Hullinger, H.: New benchmarks in higher education: student engagement in online learning. J. Educ. Bus. **84**(2), 101–109 (2008)
5. McBrien, J.L., Jones, P., Cheng, R.: Virtual spaces: employing a synchronous online classroom to facilitate student engagement in online learning. Int. Rev. Res. Open Distance Learn. **10**(3), 1–17 (2009)
6. Chen, P.-S.D., Lambert, A.D., Guidry, K.R.: Engaging online learners: the impact of web-based learning technology on college student engagement. Comput. Educ. **54**, 1222–1232 (2010)
7. Dixson, M.D.: Creating effective student engagement in online courses: what do students find engaging? J. Sch. Teach. Learn. **10**(2), 1–13 (2010)
8. Dabbagh, N., Kitsantas, A.: Using learning management systems as metacognitive tools to support self-regulation in higher education contexts. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 197–211. Springer, New York (2013)
9. Vollmeyer, R., Rheinberg, F.: The role of motivation in knowledge acquisition. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 697–707. Springer, New York (2013)
10. Clark, R.C., Mayer, R.E.: E-learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning, 3rd edn. Pfeiffer, San Francisco (2011)
11. Scanlon, E.: Mobile learning: location, collaboration and scaffolding inquiry. In: Ally, M., Tsinakos, A. (eds.) Increasing Access Through Mobile Leaning. Commonwealth of Learning and Athabasca University, Canada (2014)
12. Weinberger, A.: Principles of transactive computer-supported collaboration scripts. Nordic J. Digital Literacy **6**(3), 189–202 (2011)
13. Hseih, H.-F., Shannon, S.E.: Three approaches to qualitative content analysis. Qual. Health Res. **15**(9), 1277–1288 (2005)
14. Elo, S., Kyngäs, H.: The qualitative content analysis process. J. Adv. Nurs. **62**(1), 107–115 (2008)
15. Kracauer, S.: The challenge of qualitative content analysis. Public Opin. Q. **16**(4), 631–642 (1952)
16. Forman, J., Damschroder, L.: Qualitative content analysis. In: Jacoby, L., Siminoff, L.A. (eds.) Empirical Methods for Bioethics: A Primer, pp. 39–62. Elsevier Publishing, Oxford (2008)
17. Strijbos, J.W., Martens, R., Prins, F., Jochems, W.: Content analysis: what are they talking about? Comput. Educ. **46**, 29–48 (2006)
18. Abrami, P.C., Bures, E.M., Idan, E., Meyer, E., Venkatesh, V., Wade, A.: Electronic portfolio encouraging active and reflective learning. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 503–515. Springer, New York (2013)

19. Brown, J.S., Duguid, P.: Organizational learning and communities-of-practice: toward a unified view of working, learning, and innovation. Organ. Sci. **2**(1), 40–57 (1991)
20. Lave, J., Wenger, E.: Situated Learning: Legitimate Peripheral Participation. Cambridge University Press, Cambridge (1991)
21. Looi, C.-K., Lim, W.-Y., Chen, W.: Communities of practice for continuing professional development in the twenty-first century. In: Voogt, J., Knezek, G. (eds.) International Handbook of Information Technology in Primary and Secondary Education, pp. 489–505. Springer, New York (2008)
22. Selwyn, N.: Apart from technology: understanding people's non-use of information and communication technologies in everyday life. Technol. Soc. **25**, 99–116 (2003)
23. Brett, C.: Off-line factors contributing to online engagement. Technol. Pedagogy Educ. **13**(1), 83–95 (2004)
24. Davis, F.D., Bagozzi, R.P., Warshaw, P.R.: User acceptance of computer technology: a comparison of two theoretical models. Manage. Sci. **35**(8), 982–1003 (1989)
25. Venkatesh, V., Davis, F.D.: A theoretical extension of the technology acceptance model: Four longitudinal field studies. Manage. Sci. **46**(2), 186–204 (2000)
26. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User acceptance of information technology: toward a unified view. MIS Q. **3**, 425–478 (2003)
27. Cheung, R., Vogel, D.: Predicting user acceptance of collaborative technologies: an extension of the technology acceptance model for e-learning. Comput. Educ. **63**, 160–175 (2013)
28. Morgan, K.: Technology integration in multicultural settings. In: Specter, J.M., Merrill, M.D., Elen, J., Bishop, M.J. (eds.) Handbook of Research on Educational Communications and Technology, 4th edn, pp. 867–871. Springer, New York (2014)
29. Bower, M.: Affordance analysis – matching learning tasks with learning technologies. Educ. Media Int. **45**(1), 3–15 (2008)
30. Oztok, M., Zingaro, D., Brett, C., Hewitt, J.: Exploring asynchronous and synchronous tool use in online courses. Comput. Educ. **60**, 87–94 (2013)
31. Wang, Q.: Using online shared workspaces to support group collaborative learning. Comput. Educ. **55**, 1270–1276 (2010)
32. Leader-Janssen, E.M., Nordness, P.D., Swain, K.D., Hagaman, J.L.: Students' perceptions of an online graduate program in special education for emotional and behavioral disorders. Teacher Educ. Spec. Educ. **39**(4), 246–258 (2016)
33. Brown, T.H.: M-learning in Africa: doing the unthinkable and reaching the unreachable. In: Voogt, J., Knezek, G. (eds.) International Handbook of Information Technology in Primary and Secondary Education, pp. 861–871. Springer, New York (2008)
34. De Waard, I.I.: Using BYOD, mobile social media, apps, and sensors for meaningful mobile learning. In: Ally, M., Tsinakos, A. (eds.) Increasing Access Through Mobile Leaning. Commonwealth of Learning and Athabasca University, Canada (2014)
35. Looi, C.-K., Toh, Y.: Orchestrating the flexible mobile learning classroom. In: Ally, M., Tsinakos, A. (eds.) Increasing Access Through Mobile Leaning. Commonwealth of Learning and Athabasca University, Canada (2014)
36. Veenman, M.V.J.: Assessing metacognitive skills in computerized learning environments. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 157–168. Springer, New York (2013)
37. Stevens, R., Beal, C.R., Sprang, M.: Assessing students' problem solving ability and cognitive regulation with learning trajectories. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 409–423. Springer, New York (2013)

38. Litman, D., Forbes-Riley, K.: Towards improving (meta) cognition by adapting to student uncertainty in tutorial dialogue. In: Azevedo, R., Aleven, V. (eds.) International Handbook of Metacognition and Learning Technologies, pp. 385–396. Springer, New York (2013)
39. Leiss, D., Wiegand, B.: A classification of teacher interventions in mathematics teaching. ZDM **37**(3), 240–245 (2005)
40. Tsai, C.-W.: Do students need teacher's initiation in online collaborative learning? Comput. Educ. **54**, 1137–1144 (2010)

# Teaching Software Engineering in a Multicultural Environment

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**Abstract.** Education in multicultural environments poses challenges for both educators and students. Similarly to other subjects, software engineering teaching is faced with difficulties in the need to adapt the teaching style and contents to the various cultural backgrounds of the students. Based on a small-scale study, this paper attempts to highlight perspectives of students belonging to various cultural backgrounds on software engineering, as well as their views on the practicalities of software development.

**Keywords:** Multicultural instruction · International environments
Software engineering

## 1 Introduction

As software penetrates all aspects of the world economy and increasingly more industrial systems are software controlled, software engineering has never been more important than today. Software engineering education plays an important role and, in this era of globalization, more and more higher education institutions are internationalized. The multicultural nature of high education is complex and makes teaching challenging for educators, as well as for students.

At the same time, global software development (defined as software development in which stakeholders are geographically distributed in various parts of the world) has grown considerably due to globalization [1]. In this context, it is important to offer a solid software engineering education to future software engineers, so that they are prepared to face the challenges posed by multicultural working environments. Our paper will highlight some important aspects of teaching software engineering in a multicultural environment.

## 2 Description of Method

### 2.1 Research Setting

The results presented in this paper are based on a small-scale study conducted at a Japanese university, during a software engineering course entitled "Principles of software engineering". This is a graduate level course held in English, with the goal


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of introducing basic software engineering principles. Students learn about the necessity of software engineering as a modern engineering discipline, they study various software development models, and focus on some of the major phases in the software development life cycle. Agile methods (like Scrum), Lean Canvas business plan, as well as project planning and management, business aspects of software engineering, along with some of the basic tools used by software engineers during the development of large applications, are also introduced.

### 2.2 Method

24 students at the University of Tsukuba in Japan took part in our study; the majority of the participants were studying computer science at the graduate level (first year or second year in the master's course). Half of the participants (i.e. 12) were Chinese students, 7 were Japanese students and 5 students came from other countries (three from Brazil and one each from Mozambique and Sri Lanka). They were asked to anonymously fill in a questionnaire consisting of 22 questions (19 closed-ended questions and three open-ended questions) during one of the classes held in spring 2017. The first part of the questionnaire dealt with questions relating to class style, discussion style, as well as grading method preference. Next, participants were asked to rate cultural sensitiveness of various software development phases. Questions regarding preference for work style when developing a software product were also included. The open-ended questions tried to elicit ideas for improved software engineering classes. In the following, we will illustrate and discuss the data gathered through the questionnaire.

## 3 Results and Discussion

This section will analyze the results by dividing the questions into two categories: class-style related questions and software engineering practicalities related questions.

### 3.1 Class Style

In the first part of the questionnaire, the students were asked about their preferred class style for a software engineering course, in case of classes taking place in the students' native language. The language aspect is crucial, considering that, although the current course takes place in English, this is not the native language for the vast majority of class participants (as well as the instructor). The provided options were: lecture style (with the teacher lecturing in front of the classroom), discussion style (where conclusions are reached through continuous discussions between students and teacher), combination (half teaching, half interactive) or flipped classroom style (where students read the new materials at home, then come to class and ask questions, discuss etc.). The students were asked to provide their first choice of preferred class style, as well as their second choice. The combined results are illustrated in Fig. 1. We can observe that the most popular choice is a combination of lecture style and interactive style.

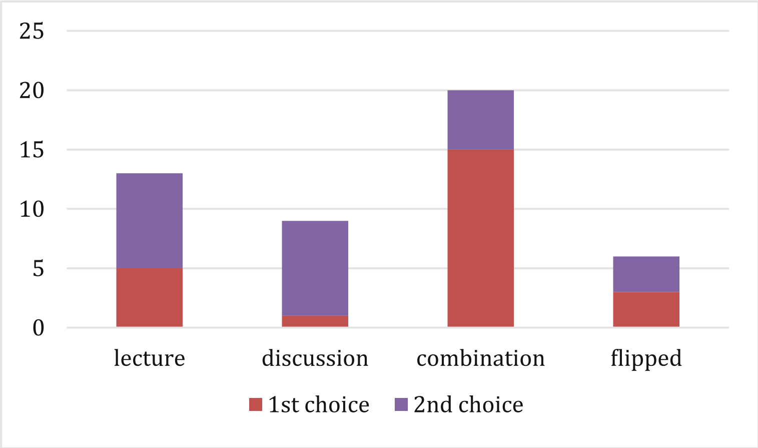


**Fig. 1.** Preferred class style (1st and 2nd choice combined)

In terms of cultural background, a larger proportion of Japanese students prefer to be more passive participants in class: 6 out of the 7 Japanese students chose the lecture style as their first or second choice, as opposed to 5 out of the 12 Chinese students and 2 out of the 5 students belonging to other nationalities. This finding is in line with previous research works on this topic, which generally states that students coming from various cultures respond to various teaching styles; Japanese students, for instance, are usually more passive during classes, tending to consider the instructors as authorities which should not be challenged [2, 3, 8].

In terms of class discussion style, the students were given the following choices: plenary discussions, groups of 3–5 people or pair discussions. Most students prefer groups discussions, i.e. 13 out of the 24; 7 students chose pair discussions. Only 4 students prefer discussions with the whole class: 3 Japanese students (out of the total of 7 Japanese students) and one students belonging to other (i.e. non-Japanese and non-Chinese) nationalities (no Chinese student prefers class discussions). We assume that this is due to the fact that plenary class discussions do not force the students to talk, simply making it easier for them to avoid speaking. Again, this finding is in line with the general perception of Japanese students as preferring to listen rather than participate actively in class.

Continuing the questions related to class discussions, a different part of the questionnaire gathered answers with regard to the main benefit of discussions, as seen by the participating students, as well as the aspects that students enjoy most when it comes to these interactions. Some students chose to select multiple options (5 students and 4 students respectively, for each of the two questions). One participant listed an additional enjoyable aspect: “listening to new, creative and interesting ideas” (as opposed to simply listening to what other people think). The results are illustrated in Table 1.

**Table 1.** Main benefit and most enjoyable aspect of class discussions

| Main benefit | | Most enjoyable aspect | |
|---|---|---|---|
| Sharing own opinion | 6 | Sharing own opinion | 7 |
| Acquiring new perspective | 14 | Listening to others | 12 |
| Forming opinion OR discovering new arguments | 11 | Hearing contradicting opinions | 7 |
| No benefit | 0 | Nothing (not enjoying discussions) | 1 |
| Other | 0 | Other | 1 |

At this point, we would like to focus on the aspect of sharing personal opinions with others. As a benefit, this aspect is listed by one out of the 7 Japanese students and by 5 out of the 12 Chinese students. As an enjoyable aspect, it is listed by one Japanese student, one non-Japanese/non-Chinese student and by 5 Chinese students. Once again, the Japanese students reaffirm their lack of preference for sharing their opinions with others.

Students were also asked to choose their preferred style of being graded for an advanced graduate software engineering course. The results are summarized in Fig. 2.

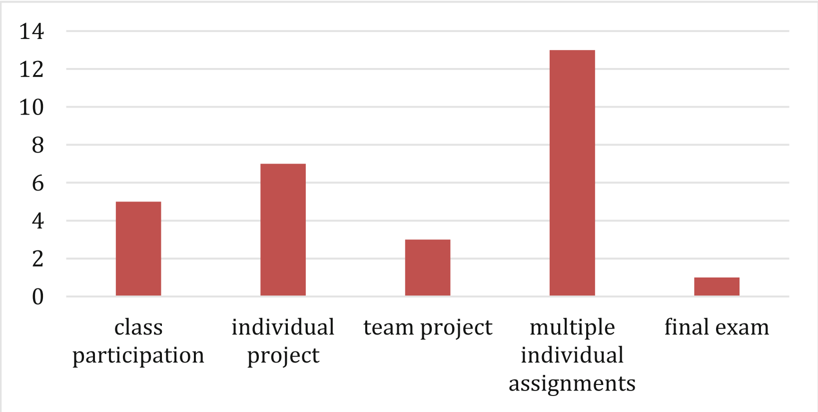


**Fig. 2.** Preferred style of grading

While only one student chose having a final exam, more than half of the participants selected multiple individual assignments as their choice of grading. Surprisingly, class participation did not appear particularly popular, despite the students' active participation in discussions, as observed by the instructor throughout the course.

### 3.2 Practical Aspects of Software Engineering

Moving on to the practicalities of software development, when it comes to developing an application, most students answered that they prefer to use agile methods, i.e. 18 students. Only 6 participants stated that they would rather use plan-driven methods. Furthermore, when asked about the preferred working style when developing an application, 4 participants chose working alone, 11 participants chose working in a team and 9 participants chose working in pairs (with a good "programmer-friend"). One student, while choosing working in a team, emphasized that this would depend on the size/complexity of the system to be developed.

In order to assess the students' perceptions of cultural sensitive aspects in software development, they were asked to rate various phases on a scale of 1 to 5 (1: low sensitivity, 5: high sensitivity). The focus was on the following phases: requirements elicitation, requirements specifications, system design, system testing and system maintenance. The results are summarized in Fig. 3.

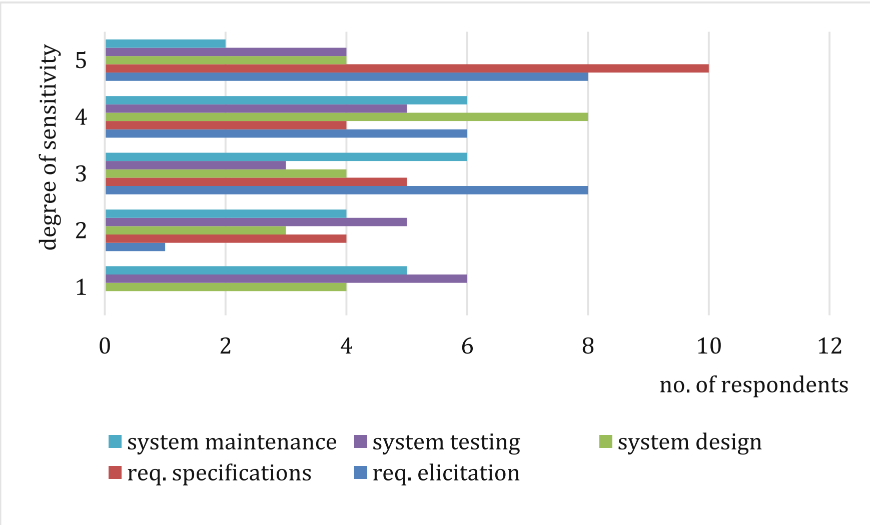


**Fig. 3.** Cultural sensitivity of various software development phases

We can observe that most participants believe that requirements elicitation have a moderately-high (3) to high (5) sensitivity. Only one participant rated this phase with 2 out of 5. Similarly, requirements specifications are considered relatively highly culturally-sensitive. On the other hand, maintenance and testing are not considered as highly culturally sensitive as requirements specifications or elicitation. Statkaityte offered a similar result in [6]; he related the sensitivity of several development phases to various dimensions in Hofstede's cultural dimension theory [2, 4].

Participants were also asked to choose the aspects in which they see cultural differences as playing an important role, when working on developing a software application in a team. 11 participants chose time (respecting deadlines etc.), 9 participants chose attitude towards colleagues, whereas 6 participants chose attitude towards the leader. Only 3 participants considered that cultural differences played a role in the actual programming style. All these results enable us to conclude that students are aware to some extent of various cultural differences and their significance when developing a software application.

## 4 Conclusions and Future Work

The various results obtained through our small-scale study emphasize the importance of including cultural aspects in the process of teaching software engineering. Through the contents of the lectures, the students must learn how multiculturalism influences aspects of software engineering, starting from the software development process of choice and ending with the actual design of the software product [5, 7].

In our future work, besides increasing the scale of our study (including a larger number of students), we intend to research the differences in course expectations, as well as the type of contents that the students are interested in. We also aim to identify how the participants' cultural backgrounds dictate the pace of the course, as well as the style. Teaching software engineering from a multicultural perspective is crucial if we want to educate future software engineers in a globalized world.

## References


1. Garbajosa, J., Yagüe, A., González, E.: Communication in agile global software development: an exploratory study. In: Meersman, R., et al. (eds.) OTM 2014 Workshops. LNCS, vol. 8842, pp. 408–417. Springer, Heidelberg (2014)
2. Hofstede, G., Hofstede, G.J., Minkow, M.: Cultures and Organizations: Software of the Mind: Intercultural Cooperation and its Importance for Survival. McGraw-Hill, New York (2010)
3. Parrish, P., Linder-VanBerschot, J.: Cultural dimensions of learning: addressing the challenges of multicultural instruction. Int. Rev. Res. Open Distrib. Learn. **11**(2), 1–19 (2010)
4. Jaakkola, H.: Culture sensitive aspects in software engineering. In: Conceptual Modelling and its Theoretical Foundations, LNCS, vol. 7260, pp. 291–315. Springer, Heidelberg (2012)
5. Filipovikj, P., Feljan, J., Crnković, I.: Ten tips to succeed in global software engineering education: what do the students say? In: 2013 3rd International Workshop on Collaborative Teaching of Globally Distributed Software Development, pp. 20–24. IEEE (2013)
6. Statkaityte, R.: Multicultural issues in software engineering processes, MSc thesis, Information Technology Pori. Tampere University of Technology, Tampere (2011)
7. Bigrigg, M.W., Filipski, K.J.: Teaching a multicultural perspective in software engineering. In: 37th Annual Frontiers in Education Conference-Global Engineering (FIE 2007), pp. S4E-1. IEEE (2007)
8. Kim, J., Meyers, R.: Cultural differences in conflict management styles in east and west organizations. J. Intercult. Commun. 29 (2012). http://immi.se/intercultural/

# Stress Coping Strategies in University Students

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**Abstract.** Psychological stress accompanies many typical activities of the students including examination, assignments and projects deadlines, prospective job's practice applications etc. Individual stress coping strategies depend on personality traits, personal maturity and stress management experience. Among personal traits significant influence on stress coping strategies have Early Maladaptive Schemas (EMS) which develop in early childhood under the influence of the family relations and temperamental features. For effective academic counseling and tutoring it is necessary to take into account these factors.

**Keywords:** Stress management · Academic stress · Early Maladaptive Schemas Socio-psychological adaptation

## 1 Purpose

Current study is based on the extensive counseling practice in helping university students to develop healthy stress management strategies. Further research was conducted to identify specific interrelations of the EMS and psychological adaptation to stress in university students. One of the goals was investigation of the specific influence of the childhood experience on the behavioral patterns of the students in stressful circumstances.

## 2 Approach

75 university students (23 men and 52 women, 17 to 36 years old) took part in the study, which included the use of the following methods: Rogers-Dymond Socio-Psychological Adaptation Inventory, Plutchik Life Style Inventory (LSI), Lazarus Coping Test, Young Schema Questionnaire (YSQ), Schema Mode Inventory (SMI). The scores in the above instruments were related to the individual stress coping strategies in stressful situations during academic year.

Research continued during 2015/2016 academic year during which each student participated in two examination sessions (3 to 6 exams in each) and several credit tests.


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## 3 Methods

Using the J.Young's model of Early Maladaptive Schemas in the study of the socio-psychological adaptation and stress coping strategies of students, it is possible to identify specific emotional-behavioral profiles in stressful situations (coping styles) and to provide more targeted impact in the process of stress management counseling.

## 4 Results

The results of this study show that the more developed the EMS the less effective is the level of adaptation to different stressful situations and consequently fewer opportunities to meet current needs and to achieve the goals set. The reason for that is the influence of the EMS on the peculiarities of emotional experiences, cognitive and behavioral stereotypes in stressful situations. Inter-correlations of the above indicators have allowed revealing specific patterns of interrelations between personal traits and stress coping strategies in students. Certain maladaptive schemas are the factors for the development of symptoms in undergraduate students. Although EMS may remain relatively latent some schemas may be activated by stressful circumstances.

The poster presentation will provide specific statistical data illustrating particular findings in this research.

## 5 Conclusion

Present study adds understanding of the complexity of the interrelations between EMS and stressors, showing relevant interdependencies with adaptation abilities and life styles that can be incorporated to stress prevention programs for students. Because university years may be full of stressful events, stress management programs should include strategies to recognize and modify specific maladaptive schemas originated in childhood and influencing emotional wellbeing and ability to benefit from stress instead of surrendering to it.

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## References

1. Young, J.E., Klosko, J.S., Weishaar, M.: Schema Therapy: A Practitioner's Guide. Guilford Publications, New York (2003)
2. Young, J.E., Klosko, J.S.: Reinventing Your Life: The Breakthrough Program to End Negative Behavior and Feel Great Again. Plume, New York (1994)
3. Young, J.: Schema Therapy Inventories & Related Materials. Schema Therapy Institute, New York (2015)
4. Van Vreeswijk, M., Broersen, J., Nadort, M. (eds.): Handbook of Schema Therapy: Theory, Research and Practice. Wiley, Chichester (2012)

5. Farrell, J., Reiss, N., Shaw, I.: The Schema Therapy Clinician's Guide: A Complete Resource for Building and Delivering Individual. Group and Integrated Mode Treatment Programs. Wiley-Blackwell, Chichester (2014)
6. Loose, C., Graaf, P., Zarbock, G.: Schematherapie mit Kindern und Jugendlichen. Beltz, Weinheim (2013)
7. Thimm, J.C.: Relationships between early maladaptive schemas and psychosocial developmental task resolution. Clin. Psychol. Psychother. **17**, 219–230 (2010)
8. Brandon, R.A.: Early recollections as a trigger technique for identifying early maladaptive schemas. Diss. Abstr. Int. **61**(03), 1626B (2000)
9. Schmidt, N.B., Joiner, T.E.: Global maladaptive schemas, negative life events, and psychological distress. J. Psychopathol. Behav. Assess. **26**, 65–72 (2004)

# Continuous Assessment in Computing and Engineering Education for Improved Students' Engagement and Enhanced Learning

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**Abstract.** The aim of this paper is to discuss the approach undertaken for a number of years at two different universities, by the use of continuous assessment, to require as well as to encourage student motivation and improve learning throughout the units. The additional aim was to improve attendance that normally leads to better results for the students, which was achieved, at least partially, on the three study units considered in this paper. There is a need also to reduce the "strain" on the students as they approach the period of the majority of multiple assessments, often all at the end of the semester or the year, each of these being critical to the students passing the particular units.

**Keywords:** Continuous assessment · Student engagement · Enhanced learning Motivated learning · Computing and engineering education

## 1 Introduction

There is a need to address the continuous effective, efficient and deep learning of students, and to retain and encourage students in the interest and hence knowledge of their subject. The issue of assessment for enhanced learning has been the focus of research for some years in several countries around the world including the UK [1–3]. If this is achieved, it would hopefully extend beyond that formal education, into their continuous professional development and lifelong learning. One of the areas to hamper continuous learning is the pressures of only one or two assessments for a particular unit. By necessity, one assessment of each unit, which is normally towards the end of the

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teaching period, results in a grouping of assessments across a series of units, whether these assessments are time constrained examinations, reports, production of artefacts or presentations.

These can result in students, due to the extreme pressure on possibly a single assessment, to concentrate almost entirely on each assessment in turn as the next deadline date approaches. Unfortunately some students follow this pattern, only undertaking minimal work if these deadlines are seen to be too far in the future.

## 2 The Approach

An approach was introduced in particular units in both the universities, where different forms of continuous assessment were introduced. This approach satisfied any uncertainty about possible collusion, due to the second part of the assessment that was wholly or partially individual, such as an examination, report with presentations with a "final" individual element. The approaches to these continuous assessments were monitored by the attitude of the students, their attendance and their results overall for the units.

The students involved in these units, with the continuous assessment, were from a variety of engineering and technology disciplines from Ulster University, on diversity of Master's courses (MSc and MEng) in engineering, whereas the students from the Southampton Solent University were from a variety of computing and technology courses, in their final undergraduate year or on the second year of their undergraduate course. The new non-continuous assessment element was different for all three courses. There were group presentations with questions and there were demonstrations of working artefacts with individual components; to individual report and presentations with questions following; to a closed book examination.

## 3 Continuous Assessment of Group Working in Computing

The first example was for second year computing students, working in teams, with the students producing design documents at various stages of the development. The assessment for each stage was discussed with each team, with the final decision of the mark being made by the lecturers. The students, as a result of each of these continuous assessment meetings, could modify their design, to continue then to the next stage of the design, ready for the next assessment meeting. The final element of the assessment was by individual closed book examination.

The students liked this approach, as the regular official checks by the lecturers ensured that any lack of participation by a member of a team was noted and hence participation by all team members was encouraged. Errors at the early stage did not affect the following elements of the design and the individual marking of elements was appreciated by the students as they felt this was a fairer way to judge their individual ability. The process during these tutorial sessions was for the teams to work on the next element, while the previous completed element was being discussed and marked by the lecturer with the appropriate team. The sequence of these elements was designed so that the next element was not directly dependent on the previous element. The elements for this structured analysis and design unit were typically (A) Data Flow Diagrams, at level zero and one; (B) Entity Relationship Diagram; (C) Data Flow Diagram level two, dependent on modified A; (D) Entity Life History, dependent on modified B; (E) file and data base descriptions; (F) State Indicators for Entity Life History, dependent on modified element D; (G) full set of the design documents with text description and cross-checking between the various techniques.

The lecturers felt this encouraged the learning process as any misunderstandings by the students could be addressed almost immediately. The attendance improved, using this approach compared with previous years and the negative comments about non-participation of members of a team was considerably reduced or removed. Another advantage was felt by the lecturers by spreading the marking throughout the year, they could concentrate on marking the examinations. The students, as they were aware of it the provisional marks, subject to Examination Board etc., felt it gave the majority of them confidence for their final closed book examination. The results of this examination, of a standard type used in previous years, showed an improvement in the overall results. This led to the hope that this form of continuous assessment was improving the quality of the students' learning.

### 3.1 Continuous Assessment Using Time Constraint Tests

The second example for the final year undergraduates involved, during the unit, undertaking a series of five mainly closed book individual tests, on the five different elements of the unit, run under examination conditions but in the normal classroom. As there were a series of different groups, a number of similar tests had to be developed for each group. Together with a sixth test for each group, that includes all the five elements of the unit. This was established to provide an opportunity for a student who missed a test to make up the 20% of the continuous element of the unit assessment. As all students were given their results before the following test, (subject to Examination Board ratification of their final results), this allowed students if they wished, to improve their results, by taking the sixth test and discarding the lowest of the six results.

The views of students on this unit included:

"Quizzes every 3 weeks, helped you keep on top of always learning".
"Learning was delivered in manageable chunks, completed with small tests at the end".
" The tests made it very easy to see how much had been learned and where weaknesses were".
"The tests were useful as it showed how much was learned!"
"It helps me getting an insight to practical approaches in my field".
"Advantages of "the distributed exams and Quality Review Documents for assignment".
"Excellent idea about having small tests, good opportunity for oral presentation as well".

The final assessment was a group report, with individual elements and presentation.

Feedback was provided after each group's presentation, to the team, and to each individual member of the team. Students were encouraged in the tutorials to bring or discuss their team report and presentation, with the tutor for feedback. Students were advised how to handle any problems with team working and to maintain quality review documents which indicated clearly the amount of work undertaken by the various members within the team. These can be then used to justify an un-equal distribution of marks, which should be agreed by the students and submitted as part of the assignment.

The disadvantage of this form from the prospective of the lecturer was that as there were different groups on the same unit, on different days, it was necessary to construct sets of different but similar questions. Each set of these test sheets was sealed in an envelope by the lecturer. Just before the first group's test began a member of that group chose one of the sealed envelopes, which was then opened by the lecturer and the tests were distributed to the students of that group.

A similar arrangement was made for the second group with a member from that group choosing one of the remaining sealed envelopes, until the final group used the last envelope. This process was viewed as fair by all the groups, so there could be no suggestion of any groups being given intentionally an easier or more difficult test. The answers were written on the test sheets. The following week, each group was told their individual results and, if they wished, could be shown their sheets, but these were retained by the lecturer. Any misunderstanding identified by incorrect answers could be immediately addressed. As these sheets were not made available to the students, the questions could be reshuffled between the different sets and the majority of these re-used the following year.

## 4 Continuous Assessment of Group Working in Engineering

The MSc/MEng study module, Product Innovation, was a core unit that regularly required the students on this unit to design, build and test a new product, working in teams, maintaining a weekly project meeting. This involved peer assessment of the week's outcome from each member of the team. These meetings were documented by the students, and supervised by the lecturers. The final element represents 95% of the unit assessment mark. There is a final presentation and demonstration by each team, with individual elements.

### 4.1 Product Innovation Module - Rationale, Aim and Delivery Methods

The rationale of the Engineering Interdisciplinary Master's degree unit of study (module) called, Product Innovation, is based on the premise that the engineering graduate of today is expected to participate in the management and control of the total technology based innovation activity within a modern industrial and commercial environment. This unit of study (module) creates knowledge and understanding of the process, skills and techniques required in generating innovation products, processes and systems. The teaching and learning is largely through the activity of solving an industry-focused client generated brief. The module aims to provide participants with the capability to improve the competitiveness of their companies through new product and/or process innovation. Emphasis is placed on teamwork, interdisciplinary management, concurrent engineering principles, technical appraisal, commercial appraisal, management evaluation and review techniques. The delivery is via lecture, group work, presentations, students' workshops and seminars, a project is completed which involves the design and manufacture of innovative product prototype.

### 4.2 Results and Students' Evaluation

The results of the group presentation and reports were quite positive as all groups worked together and on assessment passed well. Contributions of individuals to the group work were reported as separate items in appendix of the group's report.

In seeking to understand the level of impact of the use of continuous assessment on the students and the course, a student evaluation was conducted using a questionnaire. Some five questions have been identified and analyzed to obtain answers to the questions aimed at shedding light on issues of feedback, time for learning and understanding, interaction with tutors, engagement and deep learning and realization.

The five point Likert scale was used to measure respondents' agreement with a variety of statements. This scale was used to assess the level of agreement or disagreement of a symmetric agree-disagree scale. The statements amongst others include:

- Staff put in a lot of time commenting on Students work – Staff Feedback
- We were generally given enough time to understand the things we had to learn – time to Understand and Learn
- We often discussed with our lectures/supervisors how we were going to learn in this course/project – Interaction with Tutors
- It would be possible to get through this project/course just by working hard around presentation/exam times – Engagement and Deep Learning
- This course/project really tries to get the best out of all its students – Realizing Students Potential

Figures 1, 2, 3, 4 and 5 shows the results of the evaluation. Although 55% of respondents remained neutral, the number of students who believed that staff put in a lot of time in commenting on their work was 32% compared to 13% who disagreed (Fig. 1).

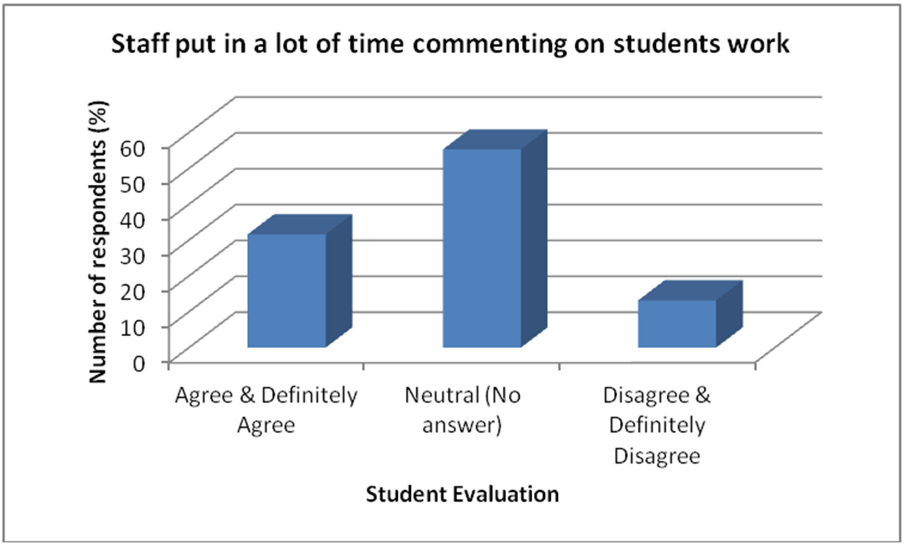


**Fig. 1.** Students' evaluation in response to staff feedback on their work

More than 60% of the students reported that they experienced being given enough time to understand the things they had to learn (Fig. 2). 37% remained neutral and gave no answer while only 2% disagreed with the statement.

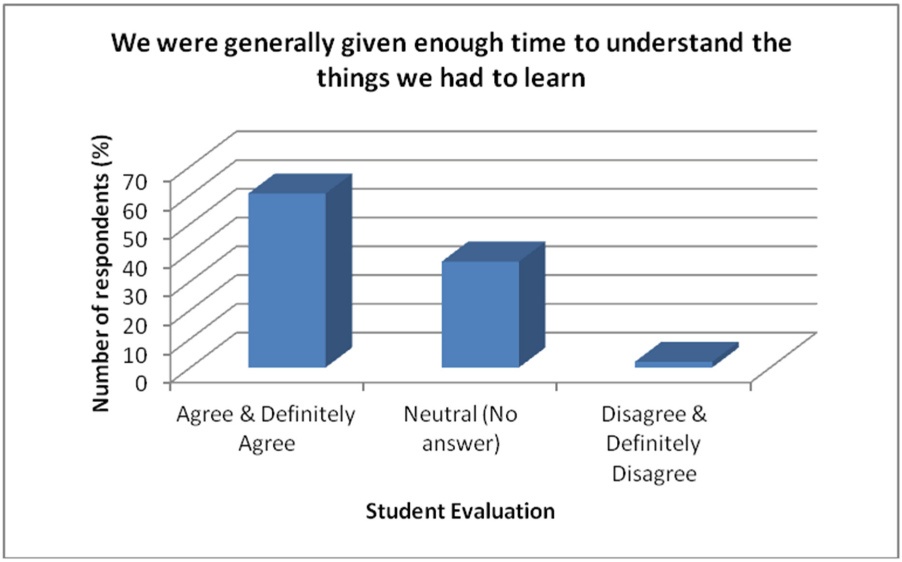


**Fig. 2.** Students' evaluation of time given for understanding and learning

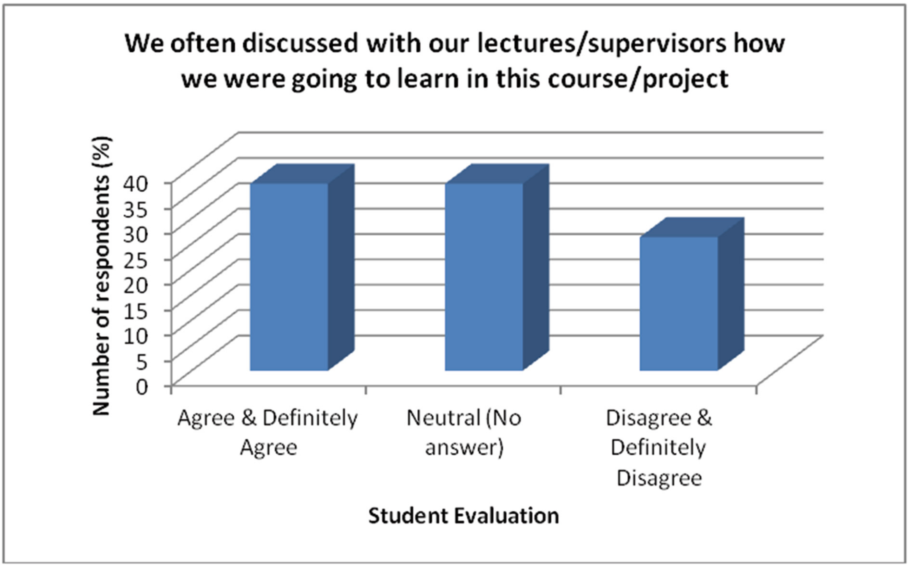


**Fig. 3.** Students' evaluation of interaction with lectures/supervisors

For effective learning the three levels of interaction has to be maintained. These include student – student interaction, student-instructional material interaction and student-tutor interaction. An equal number of students often discussed with tutors/supervisors on how their project were going to proceed, as well as those not answering (37%) in each case in Fig. 3. Up to 26% disagreed with the statement. This could be attributed to the fact that some of the groups wanted to engage more with their projects more as independent innovators than seeking guidance and help at all times.

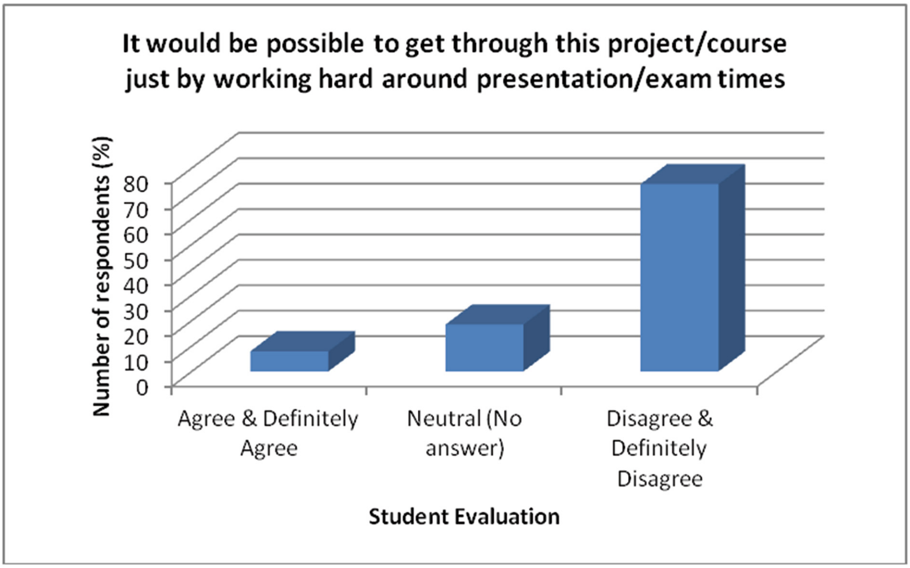


**Fig. 4.** Students' evaluation of extent and level of engagement

Figure 4 shows to a large extent, the high level of engagement with this unit of study for the postgraduate (MEng) students. Although 18% of them gave no answer and remained neutral, only 8% disagreed while 74% claimed that one can only get through the project/course at all times.

In Fig. 5, we see that a high proportion of the students agree/definitely agree that the module and project really tries to get the best out of all of them (63%), 26% of the students remained neutral while 11% disagreed. This endorses the unit of study as positively seen by students to be useful in helping them achieve own leaning goals and realize their potential.

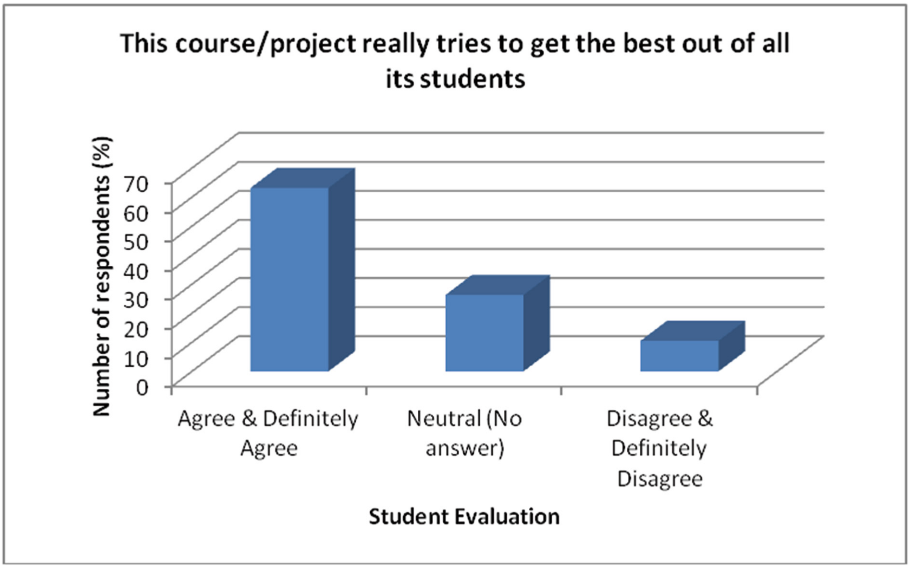


**Fig. 5.** Students' evaluation of module contribution to realizing their potential

One of the questions asked in summarizing experience and looking ahead to the future of the module requested students to state the main benefit from the module. The following are direct quotes from the students:

- Great insight on the innovation process
- Learned new skills
- Level of detail to bring a product to the market
- More awareness of how I as an individual can affect the world
- Learning about innovative process
- An insight into innovation
- Experience of innovation and product development process
- An appreciation of the complexity of innovation
- Time management of conducting projects
- Team work and product development
- Knowledge of other courses i.e. electrical engineering
- Learned about the innovation process
- Innovative knowledge
- Teamworking skills
- The feeling of being an accomplished graduate
- I have become innovative minded
- Innovative knowledge
- Confidence that I now know the techniques in product innovation
- Desire
- Independent learning

- Working in a team
- Experience in product innovation

From these extracts it can be claimed that the students had positive learning experience and gained a lot from the activities and the continuous assessment approach adopted. The use of continuous assessment allowed students to seriously engage in a practical learning process that made sense and was immediately useful in the real world solving real problems.

## 5 Continuous Assessment

Studies on the effect of CA in engineering education have shown that significantly better learning results after the adoption of CA in courses. The feedback from students also indicates higher quality of teaching as several methods of teaching are invoked and applied which compel learners to engage in effective study throughout the lifetime of the specific unit of the programme [4]. Right from the onset of the module, students became aware that their engagement, interactions and commitment will not only allow them to understand the concepts of the module and achieve the learning outcomes.

### 5.1 Feedback

Feedback is used to describe the range of processes through which students receive information about how well they understand what they are being taught and how well they are progressing with their studies. Feedback enables students to adjust and improve as they study to meet achieve the learning outcomes [5]. Throughout the lifetime of this module students were given regular feedbacks. This led to students generating a lot of interest in different aspects of the projects.

### 5.2 Results of Study, Students' Performance and Enhanced Learning

It is important to note that in the assessment of individual and group assignments. There were no cases of failures. The genuine efforts and high level of interest expressed by students in learning about innovation applied to their specific area study became quite clear. In the innovation audit conducted by each individual student, students were able to delve into details of innovation products and firms who were key players in the field.

Changes in feedback practice have the potential to positively impact learning experiences. These changes would have to be planned and implemented in a structured way such as use of guidelines or specification of feedback dates [6]. In this unit used for the present research study, feedback to students at both individual and group level was continuous. Weekly meetings attended by tutor ensured that the guidance needed and help need to make progress and enhance the learning experience was always available. The involvement of peers and other members of subject teaching team prove useful, providing a coordinated approach for enhanced practice for this innovation module.

The use of peer assessment has made for valuable learning experience for students on this module. Through critically reviewing and applying assessment criteria to the work of their peers students are able to learn a lot about their own attempts at completing tasks and are able to compare their judgments about efforts on tasks with those of their fellow students [7].

## 6 Conclusion

The effectiveness of these three similar but different approaches, each of which was used for a number of years, was to improve the attitude of students. Their views were obtained by various means, including discussion, focus groups, questionnaires, anonymous university student evaluation of all individual units. The attendance figures and the marks obtained by the students, compared with other units which the same students took, and against the results from similar cohorts of students before continuous assessment was introduced, were compared. The views of the lecturers, including both authors, were sought, identifying the advantages both from the student and lecturer's perspective, as well as the disadvantages of these approaches, including methods to minimise the disadvantages.

The results indicate that there was continuously better attendance with similar or higher grades attained in both the continuous elements and the final elements of these units. The effect in the latter, which had not been changed by the introduction of continuous assessment, implied that the learning was possibly more effective [8, 9]. A series of interviews are being undertaken a few years after the conclusion of these courses to attempt to identify if the long term effectiveness of this approach was successful.

The positive use of continuous assessment in computing and engineering education encourages and motivates students to learn and to use approaches that promote deep understanding in learning [10, 11]. Students learn in part to be assessed. Continuous assessment could be used as an instrument of coercion making students learning to be assessment led [12]. Addressing the practical and real issues of pressures on teaching and learning [13], such approaches have potential to address the excessive demands on tutor and student time and resources. We conclude that continuous assessment is an efficient way of creating and sustaining a well functioning programme of study in computing and engineering. It provides real-time information about students' learning enabling tutors and institutions to make necessary changes for sustainable development and progress.

## References

1. Juwah, C., Macfarlane-Dick, D., Matthew, R., Nicol, D., Ross, D., Smith, B.: Enhancing student learning through effective formative feedback. Higher Education Academy, UK (2004). https://www.heacademy.ac.uk/system/files/resources/id353_senlef_guide.pdf. Accessed 7 July 2017
2. Boud, D.: Implementing Student Self-Assessment. Higher Education Research and Development Society of Australia, Sydney (1986)
3. Boud, D.: Sustainable assessment: rethinking assessment for the learning society. Stud. Contin. Educ. **22**(2), 151–167 (2000)

4. Tuunila, R., Pulkkinen, M.: Effect of continuous assessment on learning outcomes on two chemical engineering courses: case study. Eur. J. Eng. Educ. **40**(6), 671–682 (2015)
5. Cowan, J.: Assessment for learning – giving timely and effective feedback. Exchange **4**, 21–22 (2003)
6. Rust, C.: The impact of assessment on student learning – how can the research literature practically help to inform the development of departmental assessment strategies and learner-centred assessment practices. Act. Learn. High Educ. **3**(2), 145–158 (2002)
7. Race, P.: A Briefing on Self, Peer and Group Assessment. LTSN Generic Centre, York (2001)
8. Harlen, W., Crick, R.D.: Testing and motivation for learning. Assess. Educ. **10**(2), 169–207 (2003)
9. Higgins, R., Hartley, P., Skelton, A.: Getting the message across: the problem of communicating assessment feedback. Teach. High. Educ. **6**(2), 269–274 (2001)
10. Rowntree, D.: Assessing Students: How Shall We Know Them? Kogan Page, London (1987)
11. Marton, F., Säljö, R.: On qualitative differences in learning. II. Outcome as a function of the learner's conception of the task. Br. J. Educ. Psychol. **46**, 115–127 (1976)
12. Trotter, E.: Student perceptions of continuous summative assessment. Assess. Eval. High. Educ. **31**(5), 505–521 (2006)
13. Lines, D., Gammie, E.: Assessment methods report. Education Committee of the International Federation of Accountants. http://www.ifac.org/Education/downloads/Assessment_Methods_Report.pdf. Accessed 7 July 2017

# Lifelong Learning

# Curricula Design of Teacher Training in the Area of Didactic Technological Competences

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**Abstract.** The authors in their contribution present conceptual and methodological background of a research aimed at improving pre-graduate teacher training in the area of didactic technological competences. The main goal of the prepared research is to modernize and optimize relevant parts of study programs of teacher trainees at Slovak higher education institutions, i.e. to optimize inclusion of the relevant subjects into the study programs as to both their content and time allocation. Following this goal, in the first phase of the research there has been prepared a questionnaire survey of the current state and perspectives of the continuing professional development of primary and secondary school teachers contributing to their didactic technological competences improvement and development. In the paper there are summarized main results of the pilot test of the created questionnaire, the purpose of which was to verify the questionnaire reliability. The data gathered in the pilot test were processed and the reliability of the created questionnaire was approved by means of reliability/item analysis. The total reliability of the questionnaire was calculated through the Cronbach alpha coefficient. The obtained results show a high level of the internal consistency of the created research tool and ensure a reliability of the broader research data collection which will follow.

**Keywords:** Teacher training · Teacher professional profile
Didactic technological competences

## 1 Context of the Research and Its Goals

Didactic technological competences constitute increasingly important integral part of a teacher professional profile as they significantly influence teaching performance quality and efficiency of every teacher [1–4]. In principle all higher education institutions offering study programs in teacher training have incorporated in these programs some


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subjects or courses aimed at the didactic technological competence training. However in practice there are considerable differences in numbers of the relevant subjects included in the study programs, their position within the study program structure, in syllabi of these subjects as well as time allocation assigned to them [5].

A question is how an optimal model of the pre-gradual teacher training in the area of didactic technological competences should be designed, which aspects of the current requirements on the teacher competence profile and quality teaching assurance should be met and how these should be incorporated into the appropriate optimal training model [6]. To find out answers to these questions has become a task of a research, financially supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic, main goal of which is to support modernization and optimation of the pre-gradual teacher training related to formation and development of teacher trainee professional didactic technological competences.

In the first phase of the research, the current state and perspectives of the continuing professional development of primary and secondary school teachers in Slovak Republic relating to the development and improvement of their didactic technological competences were surveyed. The survey was based on the screening of the in-service teachers' opinions and attitudes about this issue.

In the second phase of the research, an analysis of the inclusion of different subject and courses focussed on the use of modern digital technologies in primary and secondary education (ISCED 1, ISCED 2 and ISCED 3) in teacher training study programs at various Slovak higher education institutions will be done. Additionally to the Slovak higher education institutions the same analysis will be done for some selected higher education institutions in abroad. Assessment of the observed subjects (courses) content (syllabi) will be done from the students – teacher trainees' point of view.

Taking into consideration historically common and at present very similar development of the system of education in Slovak and Czech Republic, Czech Republic was chosen as a comparative country for the research purposes. In both countries research samples of students – teacher trainees will be constituted based on their availability for the research team. In particular the research samples will consist of students enrolled in teacher training study programs of selected specialization (majors) at Faculty of Education, Comenius University in Bratislava, Faculty of Education, Constantine the Philosopher University in Nitra (Slovakia both) and Faculty of Education, Palacky University in Olomouc (Czech Republic). All mentioned faculties provide teacher training in almost identical study programs as to their specializations.

Results of the analyses processed within the first two phases of the research will be used to design a proposal of a draft of measures to innovate and modernize the corresponding parts of the pre-graduate teacher training.

## 2 Design of the Methodology of the CPD Current State Evaluation

Methodology of the analysis of the current state of the continuing professional development of primary and secondary school teachers in Slovak Republic aimed at the development and improvement of their didactic technological competences has been based on screening opinions of these teachers.

For the purpose of the screening a questionnaire involving 41 items was designed. The questionnaire items were structured into four parts:

- part A consisting of 4 nominal items (A1–A4) focused on the respondents' identification data (gender, length of service, category and sub-category of the teaching staff they belong to);
- part B consisting of 7 nominal items (B1–B7) focused on the use of interactive educational activities and digital means in respondents' teaching practice (how they use them);
- part C consisting of 13 ordinary items (C1–C13) focused on the assessment of the significance of the use of various interactive educational activities and digital means in teaching process for selected specific aspects of education;
- part D consisting of 17 ordinary items (D1–D17) focused on the respondents' self-assessment of their knowledge and skills, i.e. in principle competences, to work with software applications and digital means within the scope of their own teaching practice.

Specification of the given parts resulted from an extensive search work of available sources describing relevant research done in Slovakia and abroad, too [7–11], on consultations with experts dealing with these or similar issues and not least on personal discussions led in community of experts having extensive professional and educational experiences in tertiary education practice as well as in continuing education of primary and secondary school teachers aimed at topics relevant to our research interest area. The above-mentioned parts of the questionnaire were proposed with the intention to enable a transformation of the qualitative features of education (training) in the field of selected computer applications, digital teaching tools and objects into the quantitative characteristics, what opens broader possibilities to final evaluation using a wide scale of methods of quantitative based research.

At the nominal items B1–B7 the respondents chose from the offered alternatives the one which corresponded with their opinion best. Beside that, the items B1–B6 offered the respondents also the possibility to give other, their own response. Because all these items were of nominal character, they were not included in the process of the questionnaire reliability/item analysis.

At the ordinary items C1–C13 the respondents expressed their opinions and assessments to the use of various interactive educational activities and digital means in teaching processes taking into consideration different aspects of the teaching process. The assessment was done through a four-point scale, i.e. by assessments from 1 to 4 points where point value (1 – *insignificant*, *unimportant*, *without influence,* 2 – *rather insignificant, rather unimportant, rather without influence*; 3 – *rather significant, rather important, rather with influence*, 4 – *significant, important, with influence*). A choice of the neutral, emotionally indifferent attitude towards the given questions/statements was not included because we wanted to force the respondents to express themselves clearly and exactly. Each respondent's response to the particular ordinary items were recorded, i.e. we recorded the scale values by which the respondent evaluated impact of the interactive educational activities and digital means on the selected aspects of the teaching process (see list of aspects in the Fig. 1 Note).

Analogically in the questionnaire part D the respondents were asked to assess a level of their knowledge and skills to work with various selected software applications and digital means and to use them in frame of their teaching practice. Also here the assessment was done through a four-point Likert scale (1 – *my knowledge and skills are insuffitient*, 2 – *my knowledge and skills are rather insuffitient*, 3 – *my knowledge and skills are rather suffitient*, 4 – *my knowledge and skills are suffitient*).

As it has been above-mentioned, for a further use of the designed questionnaire as a tool for a broader research data collection we considered to be very important to verify its reliability. This was done in a pilot test.

## 3 Assessment of the Reliability of the Data Collection Tool

A basis of each measuring process is data collection. If the measurement is to be of an appropriate quality, the measuring procedure has to be objective, valid and reliable. In our case the reliability of the data collection tool was confirmed based on the identification of the suspicious items through the reliability/item analysis.

The reliability/item analysis belongs to multidimensional survey techniques and is used for quality assessment purposes. It can be used to assess reliability of the measuring process, in particular for example just to assess the questionnaire scale and to identify its suspicious items.

One of the direct estimations is Cronbach coefficient alpha – Cronbach's alpha

$$\widehat{\alpha} = \frac{m}{m-1} \cdot \left(1 - \frac{\sum s_j^2}{s^2}\right), \tag{1}$$

where $m$ refers to the number of questionnaire items, $s^2$ refers to the variance of the questionnaire scale (variance associated with the observed total scores) and $s_j^2$ refers to the variance associated with the item j scale.

Reliability estimation can be calculated also from the average correlation coefficient $\bar{r}$ of the particular items, according the formula

$$\overline{\alpha} = \frac{m\overline{r}}{1 + (m-1)\overline{r}}, \tag{2}$$

where $m$ is the number of items.

Standardized Cronbach's alpha can be calculated also through the previous formula (1), if all measurements were standardized in advance, what means each value of the variable to count off its mean and to divide it by its standard deviation.

If the two estimations differ, it indicates that the particular items have not the same variability [12].

## 4 Results and Their Discussion

Validation of the questionnaire was carried out at the beginning of the year 2017. The research sample of the pilot test consisted of 37 primary and secondary school teachers.

As it is above-indicated (see the part *2 Design of the methodology of the CPD current state evaluation*), only 30 from the total number of 41 questionnaire items (13 ordinary items of the part C and 17 ordinary items of the part D) were included in the data collection tool evaluation and its suspicious items identification. The total reliabilities of the two relevant parts (questionnaire parts C and D) were assessed through Cronbach's alpha, Standardized alpha and the correlation. The calculated values of Cronbach's alpha for the part C $\alpha_C = 0.8678$ and part D $\alpha_D = 0.9268$ indicate a high internal consistency of the designed research data collection tool.

At this point we would like to notice some attributes of the pilot research sample of the primary and secondary school teachers. Actually the respondents were only primary and lower secondary education teachers (ISCED 1 and ISCED 2), mostly females, with different length of their teaching practice. All respondents have already passed some continuing professional development courses, focused on enhancing their didactic technological competences (provided by different education institutions). i.e. the courses were devoted to improvement of teachers' skills to use computer applications and digital tools in their teaching practice and professional development. That is why the respondents' statements to the observed issues can be taken as relevant ones and creating a platform for the improvement of the pre-graduate teacher training study programs.

The main goal of the pilot validation of the questionnaire tool was to find out from the respondents' point of view, which components were causing problems, to be able to relieve eventual shortages, whether of the formal, technical, contentual or methodological character. From the statistical point of view, the size of the pilot research sample was large enough to use the statistic methods to assess the questionnaire reliability and to identify its suspicious items. Following the obtained results the questionnaire was modified into its final version.

Thereinafter, we present a deeper analysis of the results of the questionnaire part C verification.

### 4.1 Analysis of the Suspicious Items of the Questionnaire Part C

In the questionnaire part C the respondents, primary and secondary school teachers, were asked to express their opinion on incorporation interactive education activities into the teaching process. They were asked to evaluate a level of significance of their use in the teaching process from the point of view of different aspects of education (list of the aspects see in the note at Fig. 1).

On the basis of the reliability/item analysis, the suspicious items, which decrease the total questionnaire reliability and have the most serious influence on the mean value and variability of the total score, were identified.

The value of the correlation coefficient 0.86 expresses a ratio of the sum of the particular questionnaire item variability and the questionnaire total variability. Both estimations (Cronbach's alpha and standardized alpha) do not differ very much, what means that the particular items of the questionnaire part C are of the same variability (Table 1).

**Table 1.** Overall questionnaire statistics

| | | | |
|---|---|---|---|
| Number of the questionnaire items | | 13 | |
| Number of valid responses | | 37 | |
| Mean | 42.1081 | | |
| Standard deviation | 5.6852 | Cronbach's alpha | 0.8613 |
| Average correlation between the items | 0.3377 | Standardized alpha | 0.8613 |

From the point of view of the given item group, the questionnaire shows to be reliable, however the low value of the average correlation between the items (0.3377) indicates that some items elimination (their removing) could even increase the questionnaire reliability.

The graph in Fig. 1 shows how the elimination of each particular item decreases the given Cronbach's alpha (0.8613). The only exception is the item C13, elimitation of which causes an increase of the given Cronbach's alpha (to the value 0.8787). This means that the item C13 decreases the total reliability of the designed questionnaire.

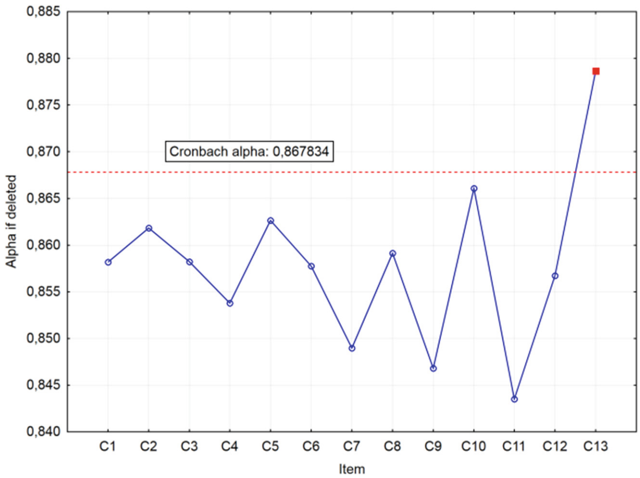


**Fig. 1.** Changes of the questionnaire reliability coefficient value after elimination of the relevant questionnaire item

*Note to Fig. 1*:

C1 – *increase of pupils' motivation*; C2 – *increase of pupils' interest in the taught subject*; C3 – *increase of pupils' activity during the lesson*; C4 – *development of pupils' creativity*; C5 – *pupils' easier understanding of the presented new subject matter*; C6 – *longer-term retention of the presented subject matter*; C7 – *increase of the pupils' skills to apply the acquired knowledge in practical task solving*; C8 – *increase of the taught subject popularity (favour)*; C9 – *increase of pupils' mutual co-operation*; C10 – *increase of* *pupils' "spirit of competitivity"*; C11 – *positive influence on pupils' disciplined behaviour*; C12 – *increase of the positive classroom climate*; C13 – *development of pupils' digital literacy.*

The graph in Fig. 2 shows values of the coefficient of determination after elimination of each relevant item. The value of this coefficient indicates to how many percentages the other questionnaire items explain the relevant item (e.g. the questionnaire item C13 is explained by the other C items approximately only on 20%).

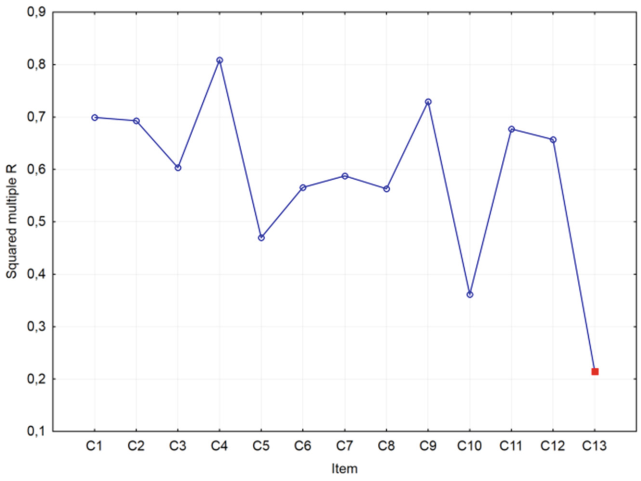


**Fig. 2.** Values of the coefficient of determination after elimination of the relevant item

From the graph presented in Fig. 3 it is clear that the total values of the standard deviation of the responses after the elimination of the relevant items are not changed

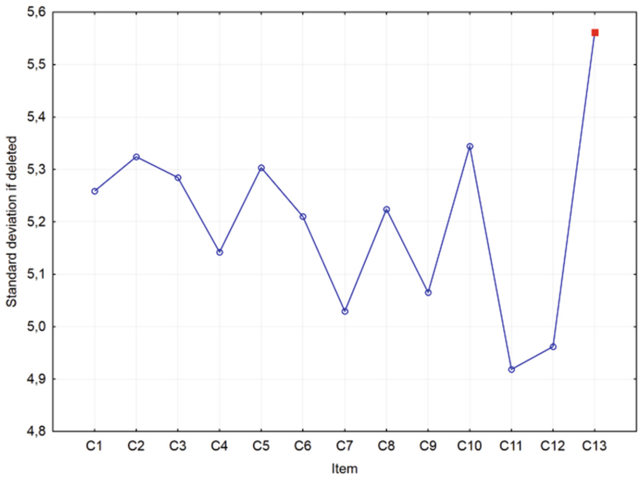


**Fig. 3.** Values of the total score standard deviation after the relevant item elimination

significantly. This statistical indicator points out the most homogeneous responses recorded in case of the questionnaire item C13 (5.5615) at which the respondents stated their opinions on the influence of the use of interactive education tasks in teaching process on the pupils' digital literacy development. After this item elimination the variability of the total questionnaire score (5.5615) was increased most significantly.

The graph in Fig. 4 presents correlations of the particular items with the total questionnaire score. A positive correlation, linear direct proportion, with the total questionnaire score was identified in case of all of the items with the exception of the item C13. This item does not correlate with the total score (0.014), what means that its values change independently. From this reason the item was identified as a suspicious one.

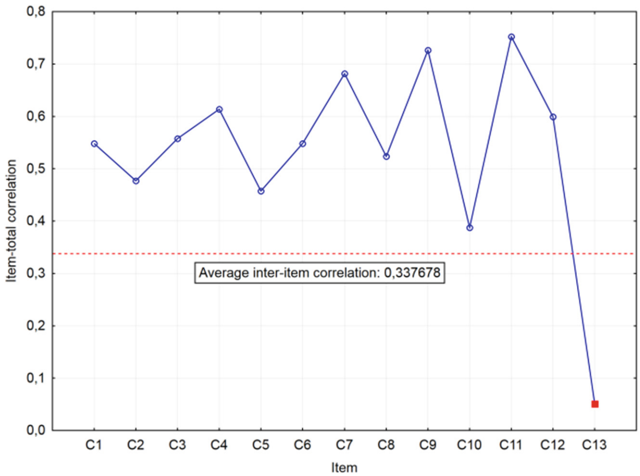


**Fig. 4.** Correlations of the particular items with the total questionnaire score

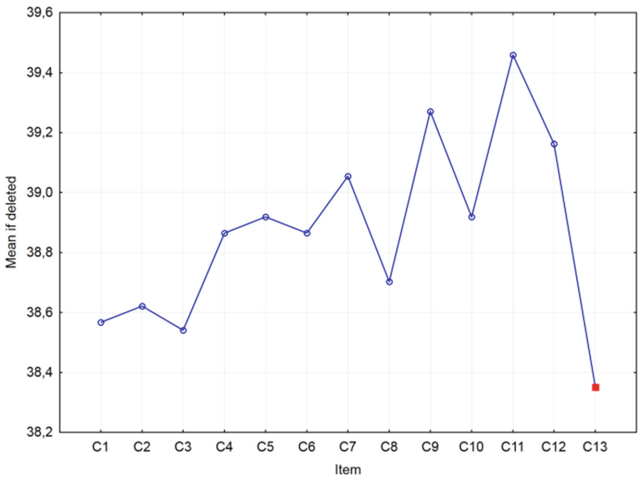


**Fig. 5.** Average values of the questionnaire total score after the relevant item elimination

Based on the graphical visualisation of the average value of the questionnaire total score after the relevant item elimination (the graph in Fig. 5) we state that just the item C13 was evaluated by the respondents very positively and after its elimination the decrease of the average questionnaire score was most marked.

## 4.2 Discussion of the Achieved Outcomes

Through the items included in the questionnaire part C, i.e. through the statements given in them, we want to find out teachers' opinions about how significant is to include interactive education activities into the teaching process to influence particular selected aspects of this process (list of the aspects see in the note to Fig. 1; 4 – *significant*, 3 – *rather significant*, 2 – *rather insignificant*, 1 – insignificant).

By the means of the reliability/item analysis the questionnaire item C13, in which the respondents assessed influence of the inclusion of interactive education activities into the teaching process on pupils' digital literacy, was identified as a suspicious one. As suggested by results from the recorded average value of the C13 score, this item belonged to those at which the respondents stated positive assessments, i.e. in the respondents' opinion inclusion of the interactive education activities into the teaching process is rather or even significant for the pupils' digital literacy development. From the C items (C1–C13) this was the one with the most homogeneous responses of the respondents. At the other C items the standard deviations indicated a greater variability of the respondents' responses to them. This means that the influence of the inclusion of the interactive eduation activities into the teaching process on e.g. the pupils' behaviour (item C11) or increase of pupils' mutual co-operation (item C9) was assessed by the respondents not so exactly as it was in case of the development of the pupils' digital literacy (item C13).

Another reason why the respondents responded to the C13 item independently on the other items could be the fact that a conceptual inclusion of the interactive education activities into the teaching of the particular subjects has not so significant direct impact on the development of the pupils' digital literacy as it is in case of its influence on pupils' subjective attitudes to the taught subjects (e.g. C1 – *increase of pupils' motivation*; C2 – *increase of pupils' interest in the taught subject*; C6 – *longer-term retention of the presented subject matter*; C7 – *increase of the pupils' skills to apply the acquired knowledge in solving practical tasks*; C8 – *increase of the taught subject popularity (favour)*) or particular aspects of the teaching process realisation (C3 – *increase of pupils' activity during the lesson*; C5 – *pupils' easier understanding of the presented new subject matter*; C9 – *increase of pupils' mutual co-operation*; C12 – *increase of the positive classroom climate*).

Untrustworthiness of the item C13 could result also from the used formulation, in meaning of unclearness of the used term *digital literacy*. On the one hand this term is used very frequently but on the other hand its content is continually changing, shifted further, and so it is difficult to state how the term was taken by the respondents.

Following the presented discussion of the result achieved by the item C13 in the reliability/item analysis, a decision was made to keep this item among the others, although it was identified as a suspicious one and its elimination increased the questionnaire reliability from the value 0.8678 to the value 0.8787. But on the other hand there is an intention to reformulate it, to make it in its meaning more exact for the target group of the respondents of the further questionnaire survey.

## 5 Anticipated Further Phases of the Research Inquiry

In the further phase of the research an analysis of the inclusion of different subject and courses content of which deals with the use of modern digital technologies in primary and secondary education (ISCED 1, ISCED 2 and ISCED 3) in teacher training study programs will be processed. The analysis will be done for a sample of Slovak higher education institutions and additionally to it also for some selected higher education institutions in Czech Republic. Assessment of the content (syllabi) of the observed subjects will be done from the students' point of view.

In the last phase of the research based on the platform of the achieved preliminary results of the first two phases a research study will be prepared which will consists of:

- evaluation of the current state of the professional training of teacher trainees in the area of the use of modern digital technologies in education processes in frame of the study programs of teacher trainees at selected Slovak and Czech higher education institutions,
- comparison of the strengths and weaknesses of the observed training in frame of the study programs of teacher trainees in Slovakia and Czech Republic,
- proposal of a draft of measures to innovate and modernize the corresponding part of the pre-graduate teacher training focused on the development of teacher trainees' didactic technological competences according to the needs and requirements of the current pedagogic practice.

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## References

1. Viteckova, M., Prochazka, M., Gadusova, Z., Stranovska, E.: Identifying novice teacher's needs – the basis for novices' targeted support. In: 9th International Conference of Education, Research and Innovation (ICERI–2016), 14–16 November 2016, Seville, Spain, pp. 7731–7738. IATED Academy
2. Gadusova, Z., Hockickova, B., Lomnicky, I., Predanocyova, L., Zilova, R.: Evaluation of teachers' competences. In: 10th International Technology, Education and Development Conference (INTED–2016), 7–9 March 2016, Valencia, Spain, pp. 6957–6965. IATED Academy

3. Jonášková, G., Harťanská, J., Jakubovská, V., Predanocyová, Ľ.: Teachers' positive and negative opinions on evaluation of their professional competences. In: 2nd International Multidisciplinary Scientific Conference on Social Sciences and Arts (SGEM–2016), 22–31 August 2016, Albena, Bulgaria
4. Müglová, D., Malá, E.: The positives and the negatives of teachers' evaluation from the point of view of evaluators and the evaluated. Slavon. Pedag. Stud. J. **6**(1), 22–36 (2017). https://doi.org/10.18355/PG.2017.6.1.3
5. Brečka, P., Valentová, M.: Model of the students' key competences development through interactive whiteboard in the subject of technology. Inf. Educ. **16**(1), 25–37 (2017). https://doi.org/10.15388/infedu.2017.02
6. Klement, M., Dostál, J., Kubrický, J., Bártek, K.: ICT nástroje a učitelé: adorace, či rezistence? p. 321. Univerzita Palackého, Olomouc (2017). https://doi.org/10.5507/pdf.17.24450926 ISBN 978-80-244-5092-6
7. Nagyová, A.: The role of classroom management in conditions of lower secondary level of education in primary schools in the Slovak Republic. In: Strategica International Conference – Opportunities and Risks in the Contemporary Business Environment, 20–21 October 2016, Bucharest, Romania, pp. 509–518. SNSPA, Faculty of Management
8. Záhorec, J., Hašková, A., Munk, M.: Development of informatics competencies of non-informatics study programme students at the ISCED 5 level. In: 10th International Scientific Conference Distance Learning in Applied Informatics (DiVAI–2014), 5–7 May 2014, Štúrovo, Slovakia. pp. 537–547. Wolters Kluwer
9. Aleandri, G., Refrigeri, L.: Lifelong education and training of teacher and development of human capital. In: Global Conference on Linguistics and Foreign Language Teaching (LINELT–2014), vol. 136, pp. 1–564. Elsevier, Procedia – Social and Behavioral Sciences, 9 July 2014. Ulvydienė, L., Rahimi, A. (eds.)
10. Petrasová, A.: Analýza vzdelávacích potrieb pedagogických a odborných zamestnancov základných škôl.Vzdelávaním pedagogických zamestnancov k inklúzii marginalizovaných rómskych komunít. MPC, Bratislava (2012). ISBN 978-80-8052-477-7
11. Bagalová, Ľ.: Pedagogické inovácie na Slovensku z pohľadu učiteľov a riaditeľov ZŠ. Priblíženie výsledkov výskumu. Štátny pedagogický ústav, Bratislava (2011)
12. Munk, M.: Počítačová analýza dát. UKF, Nitra (2011). p. 361

# OntoCIP - An Ontology of Comprehensive Integrative Puzzle Assessment Method Suitable for Automatic Question Generation

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**Abstract.** Application of the Comprehensive Integrative Puzzle (CIP) assessment method is novel in medical education. Because of its high discriminatory quality, its application in medical education increases. However, creating a CIP question can be very labor intensive and time consuming while a team of experts is needed. On the other hand, Semantic web and ontologies have proven their usefulness in fine-grain knowledge management and reasoning. This paper describes a concrete development of ontology for Comprehensive Integrative Puzzle assessment method, called OntoCIP. This ontology supports automatic question generation that will reduce workload for teachers as well as engage domain experts while keeping feasibility, reliability, and validity of CIP assessment method. Conducted evaluation of OntoCIP shows that it is suitable for the purpose.

**Keywords:** Comprehensive Integrative Puzzle · Medical education · Ontology

## 1 Introduction

Comprehensive Integrative Puzzle (CIP) emerges as one of the most promising assessment methods in medical education. Its application is spread in various field of medicine and studies show positive attitude among students [1]. It also has a high discriminatory quality because of the possibility of score differentiation [2]. However, in order to show its full potential a question must be authored by highly skilled professionals, that is often not the case due to a number of reasons including difficulty to secure the right person for the job, high cost related to engagement of specialists, etc. On the other hand, recent advancements in Semantic Web technologies facilitated emergence of a new trend in question generation that is based on use of ontologies [3, 4]. Since the CIP method is suitable for computer-based assessment [2], and with the usage of Semantic Web, this method can be significantly improved in terms of automatic question generation. Although several studies explored the generation of objective questions over ontologies, they are mostly related to multiple choice question and its variations [3, 5–7]. Research conducted to date provides no records of adoption of ontologies suitable for automatic


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generation of CIP assessment method specifically. Thus, the primary goal of this research was development of OntoCIP ontology that will be suitable for automatic generation of questions for the CIP assessment method.

## 2 OntoCIP Ontology Design

### 2.1 CIP Description

Analysis of the CIP assessment method is the first step in the corresponding OntoCIP ontology design. The assessment has format of an extended matching' crossword puzzle. It consists of 4 up to 7 rows and columns in the format of an extended matrix [1]. The left-hand column contains cells with diagnoses or brief clinical vignettes. The rest of the columns contain cells about medical history, physical exam, chest X-ray and ECG, laboratory, pathology and treatment. These cells are empty and students are expected to fill in matching data, which they select from a multiple-choice pool of options [1]. It should be noted that CIP allows adjustment of different degrees of difficulty. For example, at the lowest level, CIP contains options where each option may be used only once. That is, one medical history description (or physical exam description, treatment description, etc.) can describe only one diagnosis. CIPs with higher degrees of difficulty may offer more than six sections (columns), more than six options/distracters per section, and may include instructions that ‘each option may be used once, more than once, or not at all’ [1]. Also, not all columns have to be displayed. If some diagnosis doesn’t need Chest x-ray or ECG, teacher can chose not to display this column in the assessment.

### 2.2 OntoCIP Ontology Description

Based on the conducted analysis, several concepts and relations between them were identified that may be represented as classes and properties in the ontology. Main classes are *cip:Question*, *cip:Diagnosis* and *cip:Option*. Each individual instance of the *cip:Question* class is in a containment relation with several (from 4 to 7) instances of the *cip:Diagnosis* class and several (from 4 to 7) instances of the *cip:Option* class. In other words, each question consists of several diagnosis and options. This is modeled with properties *cip:hasDiagnosis* and *cip:hasOption*. The *cip:Option* class is further specialized into the *cip:MedicalHistory*, *cip:PhysicalExam*, *cip:ChestXRayAndECG*, *cip:Laboratory*, *cip:Treatment* and *cip:Pathology* subclasses. Based on the difficulty level, *cip:Option* class can have instances that are in relationship with one or more instances of the *cip:Diagnosis* class. This is implemented by using property *cip:describeDiagnosis*. *cip:Option* class can also have instances that are in no relationship with instances of *cip:Diagnosis* class that represent distractors in the question. If the lowest difficulty level of the CIP assessment is targeted than *cip:Option* will have instances that are in relationship with exactly one appropriate instance of the *cip:Diagnosis*. In this case, property *cip:describeExactlyOneDiagnosis* is used for implementation. However, regardless of the level of difficulty, looking at the opposite direction, each instance of the *cip:Diagnosis* class is in a containment relation with exactly one instance of the subclasses *cip:MedicalHistory*, *cip:PhysicalExam*, *cip:ChestXRayAndECG*, *cip:Laboratory*, *cip:Treatment* and *cip:Pathology*.

OntoCIP ontology is illustrated in Fig. 1. It was designed having in mind implementation in RDF(S) language with a goal to keep the resulting model "simple and small" and thus successful in practice. The full description of the class *cip:Question* and the related entities is given in the RDF implementation file[1], while its visualization can be accessed in the used online ontology editor[2].

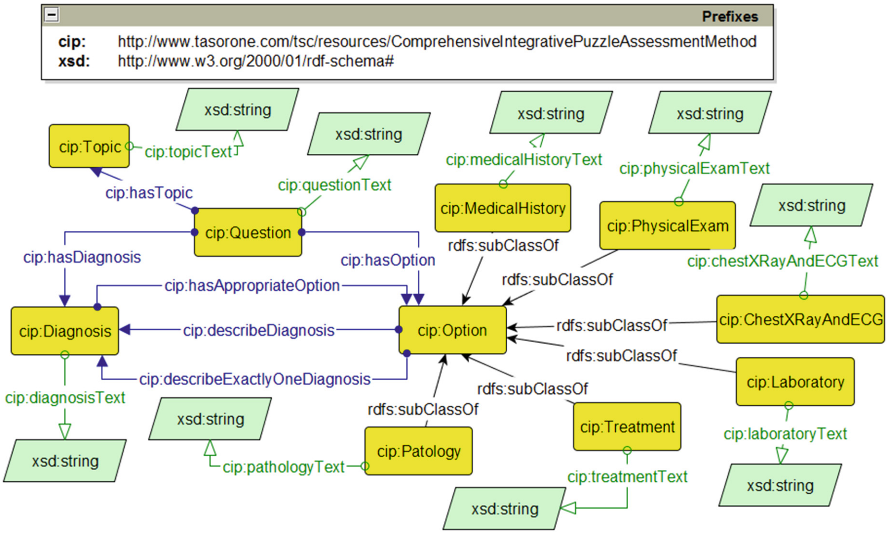


**Fig. 1.** Graphical representation of the proposed OntoCIP ontology

## 3 Question Generation Process

The main purpose of OntoCIP ontology is to support automatic CIP question generation. The process of creating a question usually takes the following steps: First, the knowledge domain is chosen and the target knowledge level is selected that teacher wants to assess. Collecting knowledge about domain that is being tested presents next step. Finally, question is generated by extracting data from domain ontologies and using some guidelines for writing questions.

Algorithm that is adopted for question generation extends the algorithm given in [4] and can be described through the following steps:

- Step 1. Select domain ontology (if several are offered)
- Step 2. Select topic to be evaluated (e.g. cardiovascular, endocrine, etc.)
- Step 3. Select number of rows (how many diagnosis will be displayed)
- Step 4. Select level of difficulty of diagnosis (use semantic similarity measure)

[1] http://www.tasorone.com/tsc/resources/ComprehensiveIntegrativePuzzleAssessmentMethod.

[2] http://www.tasorone.com/tasorone/index.html?project=TasorProjects:ComprehensiveIntegrativePuzzleAssessmentMethod.

- Step 5. Select number of columns (what concepts will be displayed, e.g. medical history, physical exam, treatment, pathology, etc.)
- Step 6. Select difficulty level of options (e.g. level 1 – each option may be used only one time, level 2 – each option may be used once or more than once, level 3 – each option may be used once, more than once, or not at all)
- Step 7. Generate question

For the purpose of our research we have used Disease Ontology[3] as the domain ontology. In order to define difficulty of generated questions and considering the hierarchical structure of the domain ontology, we have used strategy that measure semantic similarity between two concepts. Strategy is a program component that takes domain ontology and generates questions for assessment of the contained knowledge [4]. Semantic similarity [8] can be defined in different way but for the purpose of this paper we define it as a function of distance between the concepts in a graph corresponding to the hierarchical structure of the underlying ontology. The distance between two concepts [9] is a numerical representation of how far apart two concepts are from one another in some geometric space. It can be considered the inverse of semantic similarity. Figure 2 gives an example of such a distance in classification of diseases. The red solid line represents long distance between *Paratiroid gland disease* and *Mineral metabolic disease*, so they are not too similar and putting them in the same question will produce obviously ease choice for students. On the other hand *Mineral metabolic disease* and *Lipid metabolism disorder* have short distance (marked in blue dashed line), and are very similar (they are both in the same level in the hierarchy), so putting them in one question would require more knowledge about disease domain and appropriate medical history, treatment, etc., to give the right answer.

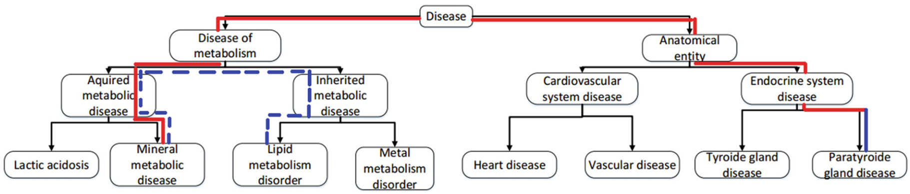


**Fig. 2.** Distance in knowledge taxonomy can affect difficulty of the question

## 4 Evaluation

Main goal of the evaluation process is to determine how suitable the proposed OntoCIP ontology is for automatic question generation. The best approach would be to use a software application that implements the automatic question generation process and measure the software complexity together with the application usability. Hence, it represents the focal point of our future work. Based on the ongoing work, we can be quite sure that the final software implementation would be based on using SPARQL as

[3] http://www.disease-ontology.org.

the standard query language for semantic web [10]. Hence, the evaluation of the OntoCIP ontology presented in this section tests is it possible to develop simple SPARQL queries [11] implementation of some complex tasks specific for the automatic question generation process.

In the OntoCIP ontology, cardinality constraints are used to express specifics about CIP methods such as the fact that, for example, instances of medical history must describe exactly one instance of diagnosis. In order to check cardinality constraints in OntoCIP ontology, we adopt the approach where SPARQL queries are used to implement decision making about fulfilment of the constraints defined in the OntoCIP ontology. One possible query that checks if the single diagnosis rule is broken (we use ASK type of SPARQL query that returns TRUE if query body returns a result) is as follows:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX cip:
<http://www.tasorone.com/tsc/resources/ComprehensiveInteg
rativePuzzleAssessmentMethod/>
# single_diagnosis_rule : returns true if broken
ASK {
  FILTER (?number_of_diagnosis> 1)
  {
    SELECT ?q (count(?s) as ?number_of_diagnosis)
    WHERE {
    ?s rdf:type cip:Diagnosis.
    ?q rdf:type cip:MedicalHistory .
    ?q cip:describeDiagnosis ?s .
    }
    GROUP BY ?q
  }

  }
```

By inspection of the query as well as its test runs, we conclude that it is efficient and simple enough. Therefore, we conclude that using OntoCIP ontology for development of user friendly and effective automatic assessment generation process is a promising approach. Note that a more general approach to treating constraints in RDF based semantic models is possible, but it is out of scope of this paper.

## 5 Conclusion

The Comprehensive Integrative Puzzle (CIP) assessment method has been proven to have high feasibility and acceptable reliability for clinical reasoning [12]. The novelty and wide adoption of this assessment method highlights the importance of its automatic generation. We have presented the process of developing ontology (OntoCIP) for Comprehensive Integrative Puzzle assessment method, which supports automatic question generation. The in-depth analysis of concepts and relations in CIP assessment method is performed thus enabling the creation of ontology. The simple evaluation process is performed by SPARQL queries, which demonstrate that OntoCIP ontology is convenient for development of user friendly and effective automatic assessment generation process. Such approach is significantly reducing workload for teachers. Apart from that, it also engages domain experts while keeping feasibility, reliability, and validity of CIP assessment method.

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## References

1. Ber, R.: The CIP (comprehensive integrative puzzle) assessment method. Med. Teach. **25**(2), 171–176 (2003)
2. Van Bruggen, L., Manrique-van Woudenbergh, M., Spierenburg, E., Vos, J.: Preferred question types for computer-based assessment of clinical reasoning: a literature study. Perspect. Med. Educ. **1**(4), 162–171 (2012)
3. Cubric, M., Tosic, M.: Towards automatic generation of e-assessment using semantic web technologies. In: International Computer Assisted Assessment Conference (2010)
4. Jelenkovic, F., Tosic, M.: Semantic multiple-choice question generation and concept based assessment. In: The First International Conference on Teaching English for Specific Purposes (2013)
5. Papasalouros, A., Kanaris, K., Kotis, K.: Automatic generation of multiple-choice questions from domain ontologies. In: IADIS e-Learning 2008 Conference, pp. 427–434 (2008)
6. Holohan, E., Melia, M., McMullen, D., Pahl, C.: The generation of e-learning exercise problems from subject ontologies. In: Proceedings of the Sixth IEEE International Conference on Advanced Learning Technologies, Kerkrade, pp. 967–969 (2006)
7. Al-Yahya, M.: Ontology-based multiple choice question generation. Sci. World J. **2014**, 9 (2014)
8. Gan, M., Dou, X., Jiang, R.: From ontology to semantic similarity: calculation of ontology-based semantic similarity. Sci. World J. **2013**, 11 (2013)
9. Lee, W.-N., Shah, N., Sundlass, K., Musen, M.: Comparison of ontology-based semantic-similarity measures. AMIA Annu. Symp. Proc. **2008**, 384–388 (2008)
10. Du Charme, B.: Learning SPARQL. O'Reilly Media Inc., Sebastopol (2011)
11. George, L., Meier, M., Schmidt, M.: SPARQLing constraints for RDF. In: Proceedings of the 11th International Conference on Extending Database Technology: Advances in Database Technology (2008)
12. Capaldi, V., Durning, S.J., Pangaro, L.N., Ber, R.: The clinical integrative puzzle (CIP) for teaching and assessing clinical reasoning: preliminary feasibility, reliability and validity evidence. Mil. Med. **180**, 54–60 (2015)

# Mobile Applications for the Prediction of Learning Outcomes for Learning Strategies and Learning Achievement in Lifelong Learning

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**Abstract.** In the age of the Internet and communication technology, changes in Technology Enhanced Learning (TEL) and Lifelong Learning Styles (LLS) are becoming a part of education and everyday life. The objectives of this paper were to develop a mobile application and provide perspectives for Learning Strategies (LS) and Learning Achievement (LA) in lifelong learning at the high school level in Maha Sarakham Province, Thailand. This research focused on the identification of the initial steps required to build academic achievement. Data collection was divided into two parts, comprised of (1) data sets for model analysis and application development from 668 students at Phadungnaree School in Maha Sarakham, and (2) data sets for application testing and level of satisfaction collected from 23 IT specialists and 72 general users at Rajabhat Mahasarakham University, Thailand. The research methodology consisted of five principal steps including (1) data collection, (2) model analysis, (3) model performance, (4) mobile application development, and (5) application implementation. The results from the model analysis showed that the research models displayed high accuracy equal to 94.51%. When developed as an association rule, the model could predict with increased accuracy equal to 98.35%. At the same time, the level of satisfaction for the developed applications was also high, equal to 4.61. Therefore, it could be concluded that this application is appropriate and reasonable for recommendation to interested parties in the future.

**Keywords:** Learning strategies · Learning achievement · Lifelong learning
Data mining in education


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## 1 Introduction

Since 1999, Thailand's education system has experienced dramatic changes. The government passed a law to promote and effect educational reform through the National Education Act B.E. 2542 (1999) [11] for the development of all education levels. The law has resulted in the development of education in Thailand towards equality and the promotion of lifelong learning as the foundation for sustainable success. Thailand's education system is free for its citizens and takes 12 years to complete. The structure follows a "6-3-3" plan, with 6 years of primary education, 3 years of lower secondary level education and 3 years of upper secondary level education. However, the Educational Statistics for Thailand in Academic Year 2014–2015 reported that significant problems continue to exist, primarily for students not attending school as required by law, as shown in Fig. 1.

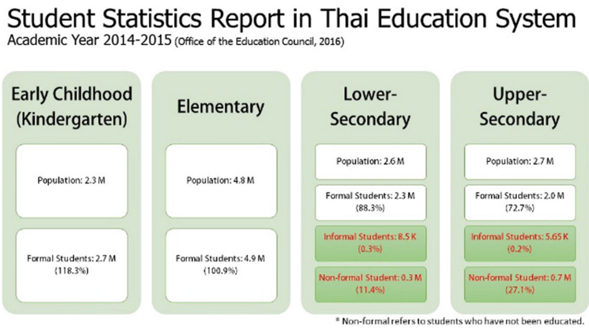



**Fig. 1.** Student statistics report (academic year 2014–2015)

Because of the considerable importance of this problem, researchers have been working for some time to resolve this issue by studying the problems of studying, proposing appropriate educational institutes' application, and identifying the factors that affect teaching and learning the most [1–3, 6]. However, researchers found that the problem of failing to meet the educational criteria and learning achievement primarily involves the availability, competency and suitability of education characterised by a learner's personality. At the same time, the number of students who drop out while studying at university is consistently on the rise.

To protect and plan for future learners, this research aims to develop applications to predict student achievement at the secondary education level. Research is based on the model through the study and research of data-mining processes, which focus on consistency with learner characteristics and lifelong education promotion.

## 2 Purpose and Goal

One of the objectives of this research is to develop a mobile application and provide perspectives for Learning Strategies (LS) and Learning Achievement (LA) in lifelong learning at the high school level in Maha Sarakham Province, Thailand. Research focused on identification of the initial steps needed to foster learning and academic achievement.

## 3 Literature Review

### 3.1 Thailand's Formal Education System

In Thailand's public domain system, the free education system takes 12 years to complete. The education structure is in accordance with the "6-3-3" project, with 6 years of elementary education (Prathom 1–6), 3 years of junior high school (Matthayom 1–3), and 3 years of high school education (Matthayom 4–6), as shown in Fig. 2.

| Typical Age | Stage | | Level / Grade | | Notes |
|---|---|---|---|---|---|
| 4 | Basic Education | Early Childhood (Kindergarten) | Variable (Typically ***Anuban 1-3***) | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | Elementary | ***Prathom 1*** | | Compulsory Education |
| 8 | | | ***Prathom 2*** | | |
| 9 | | | ***Prathom 3*** | | |
| 10 | | | ***Prathom 4*** | | |
| 11 | | | ***Prathom 5*** | | |
| 12 | | | ***Prathom 6*** | | |
| 13 | | Lower-Secondary | ***Matthayom 1*** | | |
| 14 | | | ***Matthayom 2*** | | |
| 15 | | | ***Matthayom 3*** | | |
| 16 | | Upper-Secondary | General | Vocational | |
| | | | ***Matthayom 4*** | ***Vocational Certificate (3 years)*** | |
| 17 | | | ***Matthayom 5*** | | |
| 18 | | | ***Matthayom 6*** | | |
| ... | | Higher Education | ***Variable*** | | |

**Fig. 2.** Thailand's formal education system

After graduating from junior high school, students may elect to pursue a vocational education programme, also called Dual Vocational Training (DVT), which includes two levels: a 2-year diploma for technicians, and a 3-year certificate for skilled workers.

Subsequent to the completion of high school, most students have a desire to continue their studies at higher education institutions, which comprise different types including university, technical institute, college, vocational college, and teacher college.

### 3.2 Learning Achievement (LA)

Learning achievement, also known as student achievement or academic achievement, relates to an individual's learning style in order to achieve an educational goal. In the past, the development of students' potential to realise academic achievement focused on the core assessment criteria. However, this research does not focus solely on the criteria used to judge student achievement. Rather, it emphasises student behaviour and learning styles, whose characteristics and aptitudes are important tools in the journey towards the importance of graduation.

There are many researchers who support this idea. For example, Wood et al. [4] offered a competitive approach between groups to promote and develop knowledge for learners in an engineering design curriculum. Silk et al. [5] reported a collaborative design approach in which complainants encouraged students to practice and learn additional concepts as competition scores were used as a measure of success. Nuankaew et al. [1, 2, 6] presented the concept of matching mentors and mentees with different characteristics and attributes. All concepts are consistent with a learning style called "Constructivism Learning", which believes that learning occurs through the creation of student knowledge, which happens to collaborate actively in the learning activities involved.

### 3.3 Learning Strategies (LS)

The research strategy in this research covers the curriculum and education plans developed for teaching and promoting professional education based on students' interests, which emphasise students' learning. Many researchers value student learning strategies because effective strategies have a significant impact on academic achievement. Learners often have the ability to control themselves and tend to choose the right learning strategies by themselves [7]. Winne [8] suggested that the ability of students to choose and adapt their learning strategies to their learning needs involves self-control.

In order to implement appropriate strategies for students, study of the characteristics and behaviour of the students is necessary. A series of samples in the research were aged 17–19 years and born between the years 1997 and 1999. This group was defined as Generation Z. Wood [9] proposed four trends to characterise Gen Z, including (1) interest in new technologies, (2) demand for tools and technologies that are easy to use, (3) the desire to feel safe, and (4) the desire to escape the reality of their temporary existence. The conclusion is that they have become very experienced in their short lives, having been faced with substantial political, social and technological changes.

To answer questions and create curriculum consistent with the behaviour of modern students, schools in Thailand are developing diverse courses. Phadungnaree School is one of the leading schools in the region, developing eight advanced modules including Science and Mathematics, Mathematics and Linguistics, Linguistics and Social Science, French, Chinese, Vietnamese, Business, and Music. This fact expresses the school's intention to promote foundational education.

### 3.4 Lifelong Learning Styles (LLS)

According to the 17 Sustainable Development Goals (SDGs) and 169 targets of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) [10], the purpose to ensure inclusive and quality education for all as well as promote lifelong learning is goal number 4. Major progress has been made towards increasing access to education at all levels and raising enrolment rates in schools.

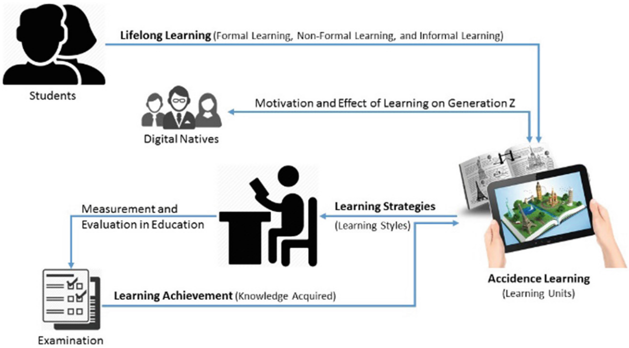



**Fig. 3.** New age learning styles

Thailand is one of the UN members whose main focus is on lifelong learning and education at all levels. As mentioned in Thailand's National Education Act of B.E. 2542 (1999) [11], the specific intent is "An Education Reform Act for Further Development of the Thai People". Therefore, studying and applying lifelong learning styles and the model must be consistent with the learner, as presented in Fig. 4.

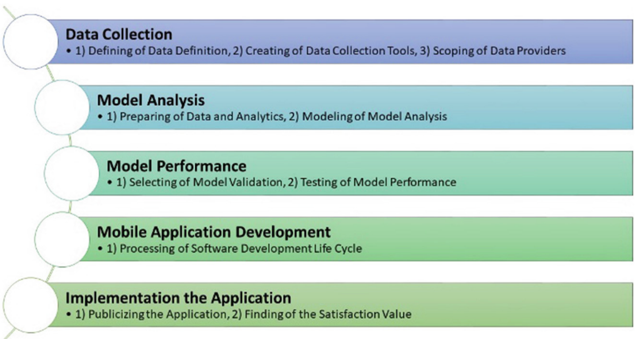



**Fig. 4.** Research methodology

Figure 4 demonstrates the new generation learning styles that affect the achievement of learning. The main components are divided into two groups, namely internal and external factors, starting with the stimuli and motivation that affect the minds of learners, called "Accidence Learning". Then the learner creates a process to develop his or her own knowledge to be satisfied, called "Learning Strategies". After that, the learner is tested to prove the acquisition of new knowledge, called "Learning Achievement".

## 4 Research Methodology Approach

The research methodology consists of five main steps including (1) data collection, (2) model analysis, (3) model performance, (4) mobile application development, and (5) application implementation, as shown in Fig. 3.

### 4.1 Data Collection

The data collection process consisted of three parts, including (1) definition of data, (2) the creation of data collection tools, and (3) the scoping of data providers.

**Defining of Data**
The data definition and attributes are categorised into two parts. The first is students' achievement, referring to the measure of overall learning outcome called Grade Point Average (GPA), while the other is academic criteria, which refers to the criteria used to determine student performance and further divided into two groups. Group I comprises students that meet the criteria (passing criteria), meaning they have an average score higher than 2.00. Group II comprises unqualified students (fail criteria), meaning their GPA is less than 2.00.

**Creation of Data Collection Tools**
The tools used to collect research data are the transcript reports of the students, which show the results of each course taken and the GPA from Grades 10 to 12 (Matthayom 4–6). Volumetric data collection was voluntary. Students did not receive any compensation, payment or reward for their voluntary involvement or the use of their reports.

**Scope of Data Providers**
A sample of the data sources was gathered from Phadungnaree School in Mahasarakham Province. Data was collected from 668 students branched into 8 majors, including Science and Mathematics, Mathematics and Linguistics, Linguistics and Social Science, French, Chinese, Vietnamese, Business courses, and Music courses. This data was collected for analysis and modelling of data mining.

### 4.2 Model Analysis

Model analysis is an important process, comprising one of the main processes in the achievement of research objectives. It consists of two parts, including (1) the preparation of data and analytics, and (2) the modelling of model analysis, which are as follows:

**Preparation of Data and Analytics**
Data preparation and analytics are performed in 6 steps as follows: (1) Problem Description aims to understand the problem in order to form a detailed plan for the

project; (2) Data Understanding links to identifying the data source received and coverage to assess the issues; (3) Data Preparation is the process of cleansing and changing relevant data into a format that can be used; (4) Creating the Models deals with the development of comparable pattern analysis techniques. (5) Evaluating the Models is related to the evaluation and assessment of the model; (6) Using the Model involves engaging in activities by applying the model.

**Modelling of Model Analysis**
Model development is a modelling process which utilises the data collected through analysis in previous steps. The process is divided into two parts, including (1) the creation of a decision tree model, which is performed by the data aggregated through process decision tree modelling [12–13] and analysis of the performance of the model with cross validation (x-validation) methods, and (2) the application of association rules, which implement the results obtained from the decision tree model generated into the specification and relationship between the data called the association rules.

## 4.3 Model Performance

The purpose of the evaluation of model performance is to select models that are effective and appropriate for application. The tool consists of two parts, including (1) the selection of model validation, and (2) testing of model performance.

**Selection of Model Validation**
The technique used to find model validation is cross validation, whose principle is to divide the data into several equal parts and then use some data sets to build the model. The remaining data sets are used to test the model. In this research, two methods are used, namely k-Fold cross validation and leave-one-out cross validation.

**Testing of Model Performance**
Performance modelling is a tool for considering specific models based on three components: accuracy, precision, and recall [2, 3].

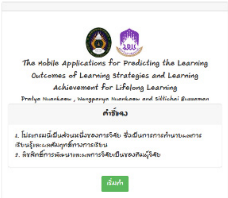
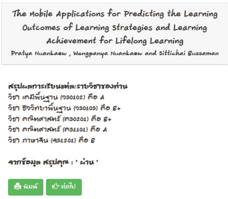
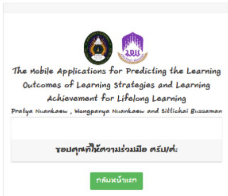
## 4.4 Mobile Application Development

This stage follows the process of software development life cycle (SDLC), which consists of five components, including requirements engineering, design and implementation, testing, release, and maintenance. After identifying the most appropriate model that could be used, the application was developed and applied to 668 students at Phadungnaree School, Maha Sarakham Province, to conduct and test the application. The interface of the application is shown in Table 1.

## 4.5 Implementation the Application

After creating the application, it was tested with 95 samples from 23 IT specialists and 72 general users at Rajabhat Mahasarakham University, Thailand. The implementation steps included (1) Publishing the application and presenting how it is used and organised as a laboratory activity, and (2) Identifying the satisfaction value. The

**Table 1.** Application interface

| Interface | Function | Interface | Function |
|---|---|---|---|
|  | This page aims to clarify the purpose and explain the details of the research. |  | This page requests the results for student academic achievement. |
|  | This page shows the results of the programme's prediction. |  | Thank you page |

research team designed and constructed a questionnaire to evaluate and ask about level of satisfaction, consisting of 4 key areas to ensure compliance with software quality, including functional requirement test, functional test, usability test, and security test as shown in Table 2.

User and volunteer participation is strictly voluntary. Apart from the results and predictions of the application, participants receive no compensation or reward of any kind in exchange for their participation. Participants were asked to score statements honestly on a 5-point Likert scale ranging from 1 to 5, with 1 indicating little to no agreement and 5 indicating high agreement with statements.

**Table 2.** Statements of questionnaires

| Perspectives and functions | Sub-topics and details |
|---|---|
| Functional requirement test | Stage 1: System ability to predict and recommend institutions |
| | Stage 2: System capabilities in service and user management |
| | Stage 3: System capabilities in data management |
| | Stage 4: System capabilities in reporting and performance |

(*continued*)

**Table 2.** (*continued*)

| Perspectives and functions | Sub-topics and details |
|---|---|
| Functional test | Stage 5: The accuracy of the results for processing |
| | Stage 6: The speed of processing for the application |
| | Stage 7: Reliability of the programme |
| | Stage 8: Coverage of programmes developed for the enterprise |
| Usability test | Stage 9: Ease of use and user responsiveness |
| | Stage 10: Appropriateness of colour, size and font of the application |
| | Stage 11: Appropriateness of using text to describe and convey meaning |
| | Stage 12: Appropriateness of using symbols or images |
| | Stage 13: Standards and design criteria for the user interface |
| | Stage 14: Appropriateness of interaction with users |
| Security test | Stage 15: Controlling access to systems, authorisation, and data control |
| | Stage 16: System failure prevention and data entry |

# 5 Results and Discussion

## 5.1 Reporting of Results

After conducting the research process, the research results include (1) the reporting of data collection, (2) the reporting of modelling and model performance, and (3) the reporting of application satisfaction, as shown in the next section.

**Reporting of Data Collection**

The collected data consists of two groups, including (1) data sets for analysis and modelling, consisting of 8 disciplines from 668 students at Phadungnaree School, Maha Sarakham Province, Thailand, as shown in Table 3, and (2) data sets for testing and determination of satisfaction. A total of 95 samples were used to test the application.

Based on the statistical data shown in Table 3, it was found that the most significant data set was in academic year 2014. This was due to having the highest number of students among data sets who did not pass academic criteria (42 students).

**Reporting of Modelling and Model Performance**

After selecting the data likely to result in unsuccessful student education, the data was calculated through the decision tree for suitability, as shown in Fig. 5.

From Fig. 5, the model was tested for performance using two techniques, namely k-Fold cross validation and leave-one-out cross validation, the results of which are shown in Table 4. At the same time, information can be converted to the association rule, as shown in Table 5. Based on this rule, the model can predict with an accuracy of 98.35%.

**Table 3.** Numbers for data collection

| Disciplines | Number of data (by academic year) | | |
|---|---|---|---|
| | 2014 (Matthayom 4) *Total/Pass/Fail* | 2015 (Matthayom 5) *Total/Pass/Fail* | 2016 (Matthayom 6) *Total/Pass/Fail* |
| Science and Mathematics | 255/249/6 (97.65%)/(2.35%) | 249/249/0 (100%)/(0%) | 249/248/1 (99.60%)/(00.40%) |
| Mathematics and Linguistics | 50/48/2 (96.00%)/(4.00%) | 48/48/0 (100%)/(0%) | 48/48/0 (100%)/(0%) |
| Linguistics and Social Science | 148/143/5 (96.62%)/(3.38%) | 143/137/6 (95.80%)/(4.20%) | 137/136/1 (99.27%)/(0.73%) |
| French | 49/32/17 (65.31%)/(34.69%) | 32/32/0 (100%)/(0%) | 32/31/1 (96.88%)/(3.12%) |
| Chinese | 35/34/1 (97.14%)/(2.86%) | 34/30/4 (88.24%)/(11.76%) | 30/30/0 (100%)/(0%) |
| Vietnamese | 69/62/7 (89.86%)/(10.14%) | 62/44/18 (70.97%)/(29.03%) | 44/41/3 (93.18%/(6.82%) |
| Business | 31/27/4 (87.10%)/(12.90%) | 27/27/0 (100%)/(0%) | 27/27/0 (100%)/(0%) |
| Music | 31/31/0 (100%)/(0%) | 31/31/0 (100%)/(0%) | 31/31/0 (100%)/(0%) |
| **Total:** | **668/626/42 (93.71%)/(6.29%)** | **626/598/28 (95.53%)/(4.47%)** | **598/592/6 (99.00%)/(1.00%)** |

**Summary of Application Satisfaction**

After designing the questionnaire and conducting the survey on selected samples, the survey results were analysed and summarised in Table 6. The overall average was highly satisfied, with the mean equal to 4.61 and standard deviation (S.D.) equal to 0.61.

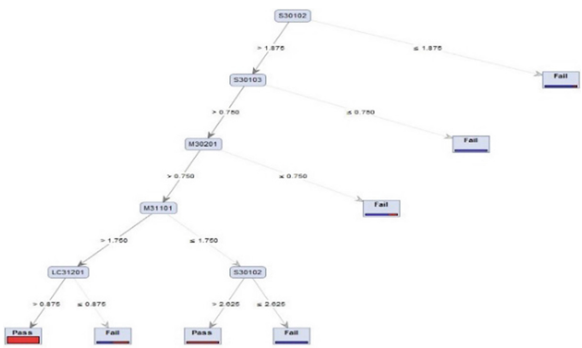



**Fig. 5.** Decision tree model

**Table 4.** Model performance analysis

| 5-Fold cross validation | | | | Leave-one-out cross validation | | | |
|---|---|---|---|---|---|---|---|
| Predicted/Actual | True condition | | Precision | Predicted/Actual | True condition | | Precision |
| | True Pass | True Fail | | | True Pass | True Fail | |
| *Predicted Pass* | 42 | 26 | **61.54%** | *Predicted Pass* | 39 | **16** | **71.43%** |
| *Predicted Fail* | 10 | 589 | **98.25%** | *Predicted Fail* | 13 | 600 | **97.86%** |
| **Recall** | **80.00%** | **95.74%** | | **Recall** | **75.00%** | **97.45%** | |
| **Accuracy: 94.51% ± 2.88% (Mikro: 94.51%)** | | | | **Accuracy: 95.69% ± 20.32% (Mikro: 95.69%)** | | | |

**Table 5.** Association rules

| Rule | Conditions | |
|---|---|---|
| | Cause (IF) | Effect (Then) |
| Rule 1 | If S30102 > 1.875 and S30103 > 0.750 and M30201 > 0.750 and M31101 > 1.750 and LC31201 > 0.875 then | Pass |
| Rule 2 | If S30102 > 1.875 and S30103 > 0.750 and M30201 > 0.750 and M31101 > 1.750 and LC31201 $\leq$ 0.875 then | Fail |
| Rule 3 | If S30102 > 1.875 and S30103 > 0.750 and M30201 > 0.750 and M31101 $\leq$ 1.750 and S30102 > 2.625 then | Pass |
| Rule 4 | If S30102 > 1.875 and S30103 > 0.750 and M30201 > 0.750 and M31101 $\leq$ 1.750 and S30102 $\leq$ 2.625 then | Fail |
| Rule 5 | If S30102 > 1.875 and S30103 > 0.750 and M30201 $\leq$ 0.750 then | Fail |
| Rule 6 | If S30102 > 1.875 and S30103 $\leq$ 0.750 then | Fail |
| Rule 7 | If S30102 $\leq$ 1.875 then | Fail |
| **Correct: 657 out of 668 training examples** | | |

### 5.2 Discussion of Results

Based on the results, the overview is a reflection of one problem found in secondary schools. Education levels in this study are the basis for students wishing to enter university, where knowledge is more theoretical than practical. The nature of the study may not be consistent with the behaviour or characteristics of some learners. Therefore, this research is conducted to offer suggestions for students to find alternative career options by choosing a more suitable field of study.

In future work, research should be expanded to application and promotion for students and their parents who wish them to continue to pursue higher education.

**Table 6.** Satisfaction towards the application

| Participants | Perspectives and functions | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Functional requirement test* | | | | *Functional test* | | | |
| | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 | Stage 6 | Stage 7 | Stage 8 |
| *IT specialists* | 4.44 (0.51) | 3.87 (0.46) | 4.00 (0.52) | 3.96 (0.48) | 4.61 (0.56) | 4.70 (0.56) | 4.04 (0.56) | 4.04 (0.48) |
| *General users* | 4.65 (0.63) | 4.53 (0.71) | 4.71 (0.62) | 4.71 (0.62) | 4.67 (0.61) | 4.60 (0.69) | 4.75 (0.50) | 4.71 (0.57) |
| ***Total:*** | **4.60 (0.61)** | **4.37 (0.72)** | **4.54 (0.67)** | **4.53 (0.67)** | **4.65 (0.58)** | **4.62 (0.66)** | **4.58 (0.59)** | **4.55 (0.62)** |
| | *Usability test* | | | | | | *Security test* | |
| | Stage 9 | Stage 10 | Stage 11 | Stage 12 | Stage 13 | Stage 14 | Stage 15 | Stage 16 |
| *IT specialists* | 4.96 (0.21) | 4.52 (0.51) | 4.09 (0.42) | 4.26 (0.45) | 4.74 (0.45) | 4.61 (0.50) | 4.26 (0.45) | 4.04 (0.47) |
| *General users* | 4.75 (0.55) | 4.72 (0.54) | 4.72 (0.54) | 4.78 (0.48) | 4.75 (0.55) | 4.69 (0.57) | 4.75 (0.55) | 4.68 (0.67) |
| ***Total:*** | **4.80 (0.49)** | **4.67 (0.54)** | **4.57 (0.56)** | **4.65 (0.52)** | **4.75 (0.53)** | **4.67 (0.52)** | **4.63 (0.57)** | **4.53 (0.68)** |

## 6 Conclusion

The objective of this work is to develop a mobile application to provide perspectives for Learning Strategies (LS) and Learning Achievement (LA) in lifelong learning at the high school level in Maha Sarakham Province, Thailand. Data collection is divided into two parts: (1) Data sets for model analysis and application development from 668 students at Phadungnaree School, Maha Sarakham; (2) Data sets for application testing and level of satisfaction collected from 23 IT specialist lecturers at the university, and 72 general users studying and working at Rajabhat Mahasarakham University, Maha Sarakham, Thailand. The results from the model analysis showed that the models were highly accurate, with a level of accuracy equal to 94.51%. Further, the model could predict with an accuracy of 98.35% when developed as an association rule. Finally, the satisfaction level for the applications is also high, which is equal to 4.61. Thus, it can be concluded that the developed applications are appropriate and reasonable for recommendation to interested parties.

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## References

1. Nuankaew, P., Temdee, P.: Determining of compatible different attributes for online mentoring model. In: 2014 4th International Conference on Wireless Communications, Vehicular Technology, Information Theory and Aerospace Electronic Systems (VITAE), pp. 1–5 (2014)
2. Nuankaew, P., Temdee, P.: Of online community: identifying mentor and mentee with compatible different attributes and decision tree. In: 2015 12th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), pp. 1–6 (2015)
3. Pupara, K., Nuankaew, W., Nuankaew, P.: An institution recommender system based on student context and educational institution in a mobile environment. In: 2016 International Computer Science and Engineering Conference (ICSEC), pp. 1–6 (2016)
4. Wood, J., Campbell, M., Wood, K., Jensen, D.: Enhancing the teaching of machine design by creating a basic hands-on environment with mechanical 'breadboards'. Int. J. Mech. Eng. Educ. **33**(1), 1–25 (2005)
5. Silk, E.M., Higashi, R., Schunn, C.D.: Resources for robot competition success: assessing math use in grade-school-level engineering design. In: American Society for Engineering Education (2011)
6. Nuankaew, P., Temdee, P.: Online mentoring model by using compatible different attributes. Wirel. Pers. Commun. **85**(2), 565–584 (2015)
7. Winne, P.H.: How software technologies can improve research on learning and bolster school reform. Educ. Psychol. **41**(1), 5–17 (2006)
8. Winne, P.H., Jamieson-Noel, D.: Self-regulating studying by objectives for learning: students' reports compared to a model. Contemp. Educ. Psychol. **28**(3), 259–276 (2003)
9. Wood, S.: Generation Z as consumers: trends and innovation, pp. 1–3. Institute for Emerging Issues: NC State University (2013)
10. United Nations General Assembly: Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015, New York, United Nations (2015). http://www.un.org/ga/search/view_doc.asp
11. Office of the National Education Commission, Office of the Prime Minister: National Education Act B.E. 2542 (1999). Office of the National Education Commission, Thailand (1999)

# Evidence of Learning Progress in Project-Based Learning on a Study Abroad Program

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**Abstract.** This paper presents a methodology using various tools to gather evidence of project-based learning for developing engineering problem-solving skills. It is part of a study abroad program designed for Japanese engineering students from mechanical, electrical and IT disciplines. In a project-based activity, the final product is assessed for learning outcomes, but the processes used to arrive at the final product also need to be evaluated carefully. In this case study, we used learner-centered processes to enable us to observe progress towards learning outcomes, and to gain insight into the thinking processes that enable success in project-based learning. Central to evaluating this process is a team workbook (either physical or electronic) including drawings, photographs and descriptions, which records all decisions, discussions and rationales for the complete design lifecycle of the project. The workbook enables us to review rejected designs, and to discuss with students both during and after the project reasons for rejections and revisions. Our case study includes three projects; The main project currently consists of conceiving, designing, building and testing a drone using a 3D printer. As students become familiarized with using the 3D printer, they recognize the need to optimize its operation to overcome printer limitations. The CAD designs are revised several times before students produce parts that can be used in the final product assembly. Keeping copies of early CAD designs serves as an excellent record of learning progress, and gives good insight into the thinking processes of project-based problem solving. The use of the 3D printer for rapid prototyping also enable students to observe directly the results of poor decision-making, without compromising their final product. If a good record of these early rejected parts is kept, together with the CAD design files, these can be used both as useful evidence of learning, and as a powerful teaching tool to explain theory and reasons for industry practice.

**Keywords:** Engineering problem solving · Engineering education
Evidence-based design model · Learner-centered environment
International collaboration

## 1 Introduction

Project-based learning (PBL) is a learner-centered approach to instruction that focuses on actively engaging students in collaborative activities with a goal of developing higher order conceptual thinking [1, 2]. Students are typically actively engaged in the whole


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lifecycle development of a product or system [1], and in solving problems to which there is no specified solution [3]. PBL can help students to develop effective design solutions under more authentic constraints [4]. Several studies of PBL in a tertiary engineering context have reported gains in learner autonomy, collaboration and problem-solving skills, as well as the ability to work more effectively with multidisciplinary, open-ended problems [1, 3]. PBL also enables learners to gain additional attributes which are important for their work-life [5].

Several factors have been identified as important in facilitating the success of PBL as an approach, including establishing a culture of student self-management, effectively using modern digital technology, and regularly monitoring and recording evidence of progress [1]. It has also been recognized that in PBL, more emphasis needs to be placed on formative assessment and the learning process and that students need to be more aware of their own learning processes [6].

Despite this, it has been claimed that evaluation of student performance in PBL is subjective and problematic [7] and there is still no widely accepted framework for engineering PBL evidence gathering, nor a guiding process for collecting evidence of learning in an engineering PBL context [8]. In this paper, we discuss our experience in changing a curriculum from a written form of assessment to project-based evaluation of learning outcomes. In this process, we hope to show that developing a systematic learner-centered approach to gathering a variety of evidence of learning across a project can be used to substantiate the learning process, and more accurately map learning from problem-solving processes to learning attributes and outcomes.

## 1.1 Study Abroad Program Structure and the Study Load

The Certificate in English and Engineering (CEE) is a 12-month study-abroad program operated by Otago Polytechnic in New Zealand for engineering students from Kanazawa Technical College in Japan, with the aim of creating engineers who are more capable of functioning in a global environment.

The distribution of the study load for the CEE program illustrated in Table 1, shows that the program is designed to have a balance between technical principles, application skills and work within a multi-disciplinary environment. Each year, the exact balance of learners from each discipline varies, but all students are required to study each of the courses below.

**Table 1.** Distribution of study load for certificate in English and Engineering

| Subject | Study load |
|---|---|
| Language skills | 50% |
| Mechanical engineering | 10% |
| Computer Aided Design (CAD) | 7% |
| Electrical principles | 7% |
| Mathematics | 16% |
| Computer programming | 10% |

Traditionally the assessment for all technical courses for CEE students consisted of well-defined convergence problems. The problems showed the underlying principles governing the subjects but had little resemblance to practical applications. For example, in the CAD course, students did not appreciate the importance of communicating concise and accurate drawing details. Students learned the skills to use the software tools, but ignored the aspects of drawing details and drawing specifications which are important for constructing and assembling a design in a workshop. Similarly, in the Mechanics course, the non-mechanical majors in the program did not require the same academic theory and consolidated knowledge, and consequently the students often rote learned the materials only to pass written assessments.

## 2 Implementation

It was recognized in the preliminary stages of implementation that students had difficulty adjusting and playing an active role within a learner-centered learning environment which is central to any PBL model functioning within a collective environment [9]. Therefore, in the second year of implementation, two preliminary projects were added to the main project to allow development of decision-making processes and to help

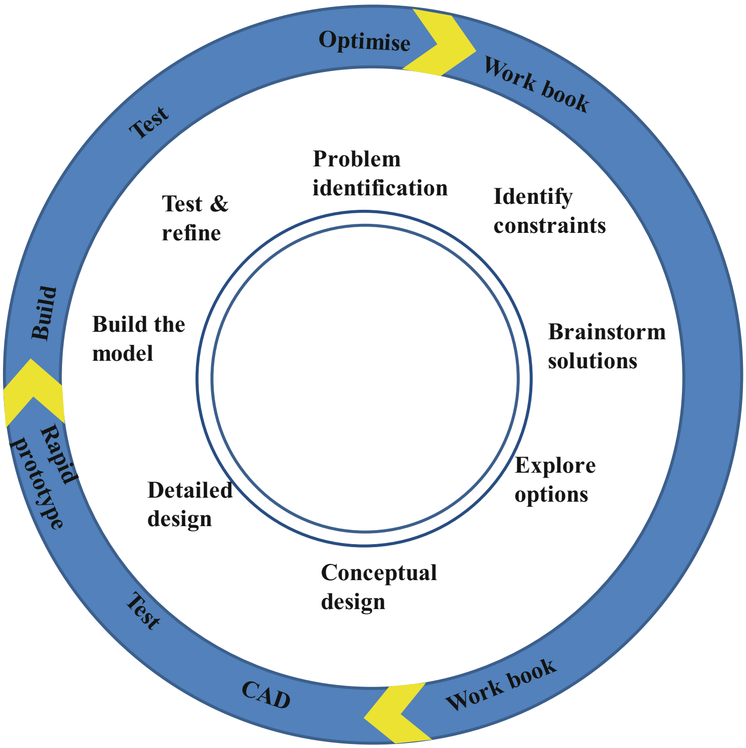


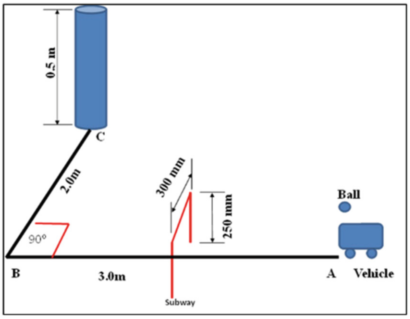

**Fig. 1.** Life cycle of a product design [5]

students adapt to a self-directed environment [5]. The students were guided systematically during every stage of the design lifecycle to follow the model described in Fig. 1 to meet the projects' design goals. These preliminary projects provided an opportunity to monitor the progress of the essential intermediate steps required for effective functioning of the teams for project completion and, if necessary, to make adjustments for effective team functioning. Group feedback sessions after project completion also help make the necessary adjustments for the successful completion of the subsequent project.

### 2.1 Team Building Focus – Project 1

This project is designed to strengthen the students' understanding of basic mechanics by providing an engineering design problem. The goal of this project is to conceive, design, construct and test a structure within well-defined limits outlined in the assessment, to hold the maximum compressive load using a limited number of popsicle sticks and joints [5]. This is a well-defined problem, and student groups have limited opportunity to work outside the specified limits (Fig. 2a). Typically, this project is given two and half weeks to complete and consists of 10% of the total marks.

a) Project 1: Structure project




b) Project 2: Car project

**Fig. 2.** Introduction to project-based learning

The project is primarily focused on developing the essential intermediate steps necessary for effective engagement within a group project environment, including:

- Facilitating team building; monitoring how respective members blend into a team
- Developing brainstorming sessions to arrive at collective decisions
- Proper record keeping of all decisions made and collection of all evidence
- Introduction to project and time management skills.

### 2.2 Introduction to Open-Ended Problem Solving – Project 2

The second project is designed to strengthen the coverage of knowledge of engineering mechanics and to develop the skills needed to solve a challenging open-ended multi-disciplinary problem that requires critical thinking and creativity. The aim of this project is to conceive, design, build and program a transport vehicle to deliver a ping pong ball to a stipulated fixed target shown using one Lego set (Fig. 2b). This project is completed in three weeks and consists of 20% of the total marks. The motivation behind this project is to resolve issues associated with solving multi-disciplinary open-ended problems:

- Providing a succession of open-ended problems with no single correct solution
- Providing the necessary skills to avoid an unstructured and unsustainable 'trial and error' approach to problem solving
- Providing the skills needed for a structured approach to opened-ended problem solving with proper understanding of the tasks to be implemented
- Providing the necessary experience to arrive at collective decisions rather than relying on the personality of an individual within the team.

### 2.3 Reflective Learning from Preliminary Project Outcomes

In our PBL model, students are taught only sufficient theory to start the projects; both technical and non-technical concerns are resolved during the design and construction phases of the project. This process reduces knowledge overload during early lessons covering underlying theory.

A major focus of our model is for students to reflect on their problems and mistakes through recording all their decision-making processes and collecting evidence of learning throughout the design lifecycle. Initially we found students attempted trial and error approaches and discarded designs when the aims were not met - a process constantly repeated throughout the design lifecycle. This lead to a lack of evidence to assess their thinking processes and problem-solving skills for mapping to learning attributes.

On completion of the two projects, the students have developed the essential intermediate steps needed to function within a self-directed environment and are familiar with essential steps required to solve open-ended problems:

In Project 1, learners recognize that the collection of evidence gives them the opportunity to make comparative studies of different models. They conduct tension and compression tests and rapid prototyping to establish the joint configuration, and truss analysis to determine the optimum structure profile for failure load.

In Project 2, students recognize the multi-disciplinary nature of the challenge and that the objective can be met with different design configurations. The device can be more mechanically complicated with simple programming control logic or mechanically simpler with more complex programming logic. Task divisions based on discipline strength become necessary, and teams recognize that maintaining a good line of communication between students is important to ensure project success. Throughout the design lifecycle, the device configuration and program control logic change regularly. The students keep records of their design changes in the workbook, taking photographs of originals, and saving the old versions of their programs. The students avoid repetition of flawed design configurations by keeping records of the design evolution.

Figure 3 summarizes the evidence-based design model students are encouraged to follow when they meet open-ended problems as the project progresses. Following this model, early design concepts and defects are not discarded. These steps help learners to avoid random trial and error repetition of defects and decisions heavily dependent on the personality of one team member. The schematic below also provides an opportunity to further evaluate design concepts rejected in the early stages of product development lifecycle shown in Fig. 1, and applies to all stages of the project cycle.

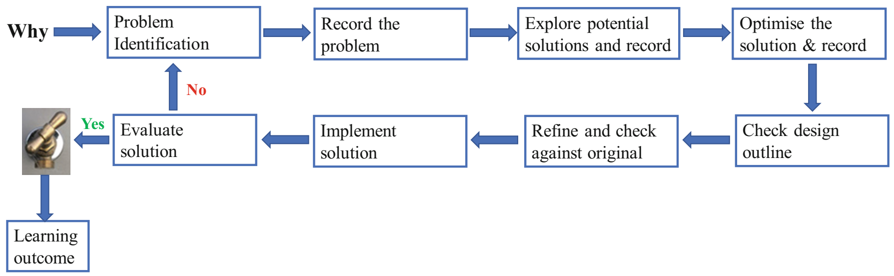



**Fig. 3.** Problem solving process

## 3 Main Project

The main project is designed to extend the skills of problem solving and novel thinking to a multi-disciplinary open-ended engineering design problem, providing an opportunity to approach an unfamiliar design challenge that has greater complexity than the previous two projects. The project duration is between two - two and half months and consists 50% of the total marks for the course. The project outline incorporates the following features:

- A multi-disciplinary approach, integrating across other engineering subjects as well as aspects of language and communication skills
- A novel problem. The project focus is changed every three to four years, so that the problems encountered are fresh for both the facilitators and the students
- Avenues to examine a problem from different perspectives to generate novel solutions

It provides students a considerable length of time to evaluate a problem, transfer knowledge from other disciplines, and apply deeper thinking to approach more complex problems associated with design.

Changing the main project every three to four years means the problem remains fresh for both the facilitators and the students. This model provides more authenticity to develop processes associated with problem-solving for facilitators and students in terms of gathering evidence based on learning. In the early years of project development, the main project was a wind turbine set in the context of the CDIO model [5].

One deficiency of the preliminary two projects was the students' inability to collect physical material evidence through the evolution of their design lifecycle. It was hard to evaluate and assess their thinking process, look at the problem from a wider perspective and generate a more systematic and structured approach to problem solving, since feedback and review was primarily based on a traditional theoretical approach carried out in the workbook. However, the reducing cost, simplicity of operation and availability of 3D printers has enabled us to integrate 3D printers into classroom learning. 3D printing allows the students to generate rapid prototyping for their design changes and assess them instantly, rather than revising based on theoretical explanations carried out in the workbook. However, in our first year we found that students quickly disposed of flawed designs or imperfect printed parts. While there is potential to gather evidence through every step of the design lifecycle, it still requires students to connect 'failures' to theory and thus improve basic knowledge, as well as reflect on deeper problem-solving skills.

### 3.1 The Contemporary Project in the CEE Program

When designing the main project for the CEE program, the selected project and the project outcome must provide adequate coverage of multi-disciplinary features and provide project integration across courses. The current main project is to conceive, design, construct and test a drone using a 3D printer (Fig. 4). A drone has sufficient coverage of mechanical, electrical and program logic control components embedded in the design. These features of drones provide an ideal platform for solving open-ended problems and provide the students with independence to decide the extent of work they intend to conduct to achieve the project goals. Project appraisal considers the following guidelines:

- Percentage of drone assembly designed and built using the 3D printer.
- Degree of innovation and originality in the design.
- Reflective learning from evidence gathering at each step of the design lifecycle.
- Drone strength, stability, length of time airborne and level of control.

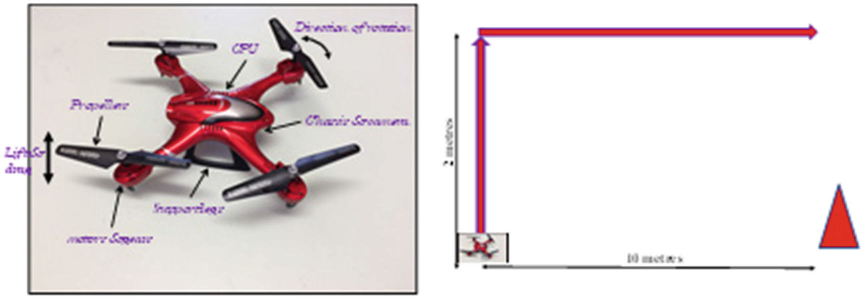



**Fig. 4.** Drone project and project goals

## 3.2 Main Project Design Steps

Figure 5 illustrates the four design steps teams deploy to design, print and assemble the drones. CAD is used to design the components for the 3D printer. The teams must understand the importance of seeing the 3D printing from a wider perspective and map precisely the strategy to disassemble the CAD design into separate elements for printing, before reassembling after printing. Learning how to tackle the vital issues associated with transferring a CAD design for printing is fundamental to project accomplishment as illustrated in Fig. 5.

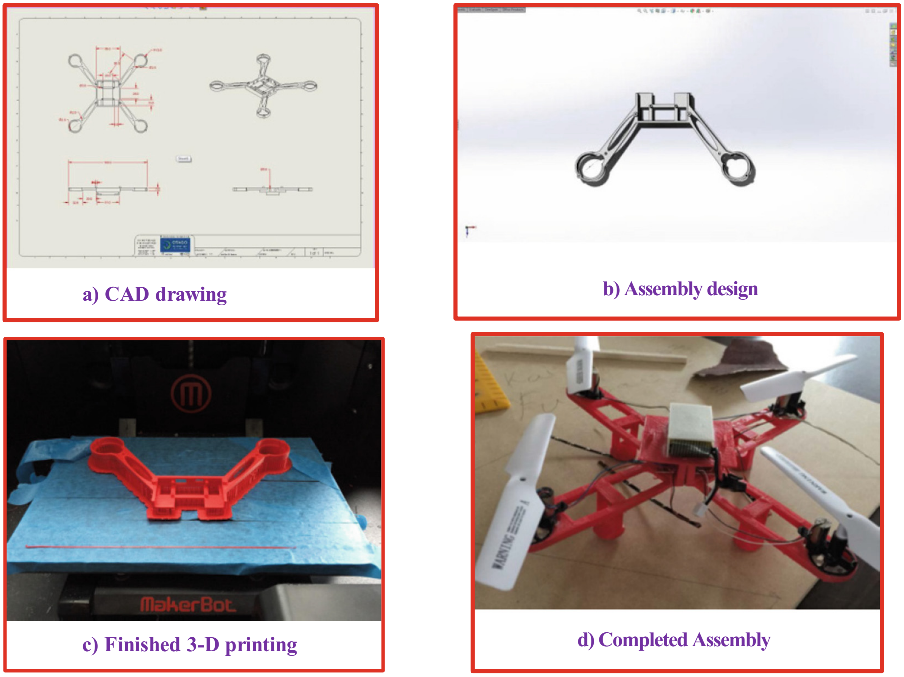



**Fig. 5.** Four main steps of design evolution

Evidence and experience have shown us that availability and proximity of the necessary tools is essential to the successful completion of the project. In the first year of implementation, student feedback indicated that better access to 3D printers would improve the project. Feedback sessions are important for the facilitators to amend shortcomings in the work environment and enhance delivery. Consequently, three 3D printers dedicated to the CEE program were located next to the regular classroom.

Convenient access to 3D printers provided the motivation for the students to engage with project activities in self-directed ways. They could execute a printing project prior to the classroom session and get on with the lesson. Then, during the short break, they could check the progress of 3D printing and adjust their design if necessary, thereby facilitating rapid rectification of design flaws.

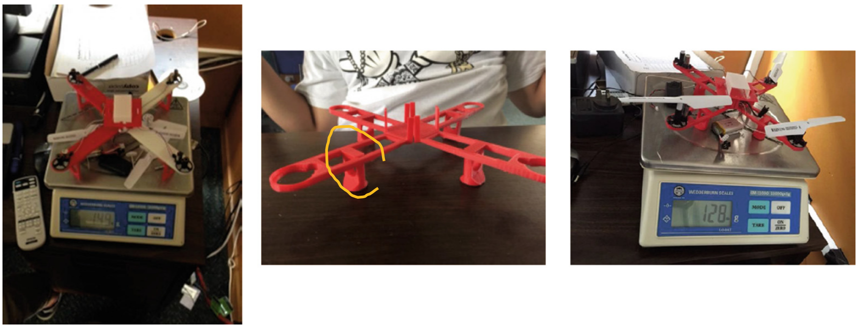
### 3.3 Assimilating Evidence Gathering and 3D Printing

The collection of evidence varies from concept to test phase of the project. At the concept stage, design ideas are recorded in a workbook as sketches with photos of proposed materials. During the initial stages, learners are constantly reminded that each new design feature that is added or changed on the original sketch or CAD drawing should be saved as a separate file. The review of those drawings provides good insight into learner thought processes, and whether problem solving is systematic and structured or unpredictable. We can assess how design flaws are identified and corrected and, more importantly, whether it has been incorporated into working knowledge.

In the 3D printing stage, students need to understand the importance of considering the limitations of 3D printer capability. When the parts to be printed are complex, it is difficult for the 3D printer to build finished products to precise specifications. Often, students need to adjust their CAD drawings to carry out necessary modifications and fine tuning. This provides further evidence for review, since the physical evidence can be used to observe the design evolution.

Groups often alternate between CAD design and 3D printing to review and reassess their design features to reduce the defects. The collection of physical evidence is very important in dealing with unfamiliar problems encountered, using the systematic method outlined in Fig. 3. This can reduce both time and materials, because, rather than rushing to solve the existing problem using limited personal experience and existing knowledge, students have the evidence with them to look at the problem from a wider perspective and review issues that were not initially obvious.

In the testing process, students may have to review all three formative processes to meet the project outcomes, and consider modifications to their original design. Experience has shown us that students often need to reconsider their original design and follow up with necessary modifications. By this stage, however, students have gained confidence to operate within an unfamiliar environment following the processes described in Figs. 1 and 3. They may need to revisit previously rejected concepts, and this can reinforce the importance of evidence gathering at this stage. Figure 6 shows an example where a team had to reduce materials to enable the drone to fly.




a) Proto-type 1 b) Saving materials c) Flying product

**Fig. 6.** Drone refinement

The model the CEE program has followed to make the transformation to PBL and improve the work environment following experience and student feedback sessions can be seen in Fig. 7, which shows that the quality and the complexity of the drones designed and constructed have improved in the three years of its implementation.

a) Year 1 b) Year 2 c) Year 3

**Fig. 7.** Design progress

## 4 Project Evaluation

Table 2 illustrates the mark distribution for project evaluation for every stage of the complete design lifecycle of conceive, design, construct and testing. The workbook consists of 20% of the total mark for the project. The groups are expected to record and discuss regularly every step of the design lifecycle from their initial design to the final product for testing, including member contribution. Students must report on the reasons for changing initial designs, determine which element did not work, how the problem was rectified, and summarize the underlying physics and what has been learnt in the process. Design and construction, where the groups allocate most of their time to complete the project constitutes 50% of the total mark. Physical evidence, photographs, original design drawings along with the revised drawings and other forms of evidence are used to evaluate their thinking processes, their understanding of underlying physics and their structured approach to problem solving. Also during the intermediate stages of design, the facilitators have the scope to intervene to provide the appropriate feedback and guidance. The testing component constitutes 20% of the total marks for meeting all the project objectives outlined in the design brief. The outcomes we have identified are:

- The groups don't replicate their mistakes
- Over 90% success in groups meeting the project objectives
- Effective time management allocated for reports and presentations.

**Table 2.** Score distribution for project evaluation

| Assessment criteria | % of total marks |
|---|---|
| Work book | 20% |
| Design and construction | 50% |
| Testing | 20% |
| Reports and presentations | 10% |

## 5 Conclusion

The process of PBL is seldom smooth, and involves various false starts and remodels. If assessment is based only on the final product, products that fail to meet all the outcomes may result in fail grades. Such assessment can easily overlook important learning processes and outcomes through the design lifecycle. To identify the processes used to arrive at the final product, a methodology needs to include careful monitoring, guiding and evaluating throughout the product lifecycle. The process we have developed requires learners to be actively engaged in recording and reflecting on their learning processes through:

1. Keeping a physical or electronic workbook that records ideas, discussions, decisions and problems throughout a project
2. Keeping electronic files of all designs and changes to those designs
3. Keeping a photographic and/or physical record of all rejected components and models from each stage of the project
4. Utilizing the problem-solving process outlined in Fig. 3 throughout the project life-cycle
5. Reflecting on evidence collected to prepare reports and presentations

One of the major benefits of using this process is the opportunities we gain to monitor progress, provide feedback and observe learning processes throughout the project, and to reflect on those changes and how they relate to engineering theory. Careful gathering of evidence of all stages of the lifecycle is important to achieve this end.

Through these projects, we have discovered that learning outcomes and project success relate less to subject discipline, and more to the proficiency and ability of students to use general problem-solving techniques and communication skills. We believe PBL has the potential to reduce the knowledge gap and align both the mechanical and non-mechanical students to more sophisticated learning processes and engage them in engineering problem solving. Consequently, the students from non-mechanical backgrounds feel that there is significant benefit in taking part in the mechanical projects, because it helps them to gain a deeper understanding of problem solving and decision-making skills. Finally, when students come to write reports and give presentations, they realize the value of keeping a careful record of 'mistakes' and 'failures', as these provide good evidence of learning.

## References

1. Kokotsaki, D., Menzies, V., Wiggins, A.: Project-based learning: a review of the literature. Improv. Sch. **19**(3), 267–277 (2016). https://doi.org/10.1177/1365480216659733
2. Biggs, J.: What the student does: teaching for enhanced learning. High. Educ. Res. Dev. **18**(1), 57–75 (1999)
3. Andrade, T.: Project based learning activities in engineering education. Int. J. Eng. Pedag. **3**(Special Issue 2), 27–32 (2013)

4. Hall, W., Palmer, S., Bennett, M.: A longitudinal evaluation of a project-based learning initiative in an engineering undergraduate programme. Eur. J. Eng. Educ. **37**(2), 155–165 (2012)
5. Weerakoon, A., Dunbar, N., Findlay, J.: Integrating multi-disciplinary engineering projects with English on a study-abroad program. In: Proceedings of the 10th International CDIO Conference, Barcelona, Spain (2014)
6. Capraro, R., Corlu, M.: Changing views on assessment for STEM project-based learning. In: STEM Project-Based Learning: An Integrated Science, Technology, Engineering and Mathematics (STEM) Approach, pp. 109–118. Sense Publishers (2013). https://doi.org/10.1007/978-94-6209-143-6_12
7. Fernandez-Samaca, L., Ramirez, J.: An approach to applying project-based learning in engineering courses. In: IEEE ANDESCON (2010). https://doi.org/10.1109/ANDESCON.2010.5630007
8. Panaite, C., Dodun, O., Goncalves-Coelho, A.: Evaluating the process of introducing project-based learning in the curriculum of engineering students. Appl. Mech. Mater. **657**, 1078–1082 (2014)
9. Pryor, C., Kang, R.: Project-based learning: an interdisciplinary approach for integrating social studies with STEM. In: STEM Project-Based Learning: An Integrated Science, Technology, Engineering and Mathematics (STEM) Approach, pp. 129–138. Sense Publishers (2013). https://doi.org/10.1007/978-94-6209-143-6_12

# International Informatic Challenge in Hungary

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**Abstract.** The significant role of ICT in everyday life could change concepts about skills, education, and learning.

The changing of definitions about necessary ICT skills (from digital fluency to computational thinking) shows that ICT skills are more about thinking and expressing yourself, exploring the range of computers and yourself, involving external representation of problem solving processes, and reflecting on your own thinking – and even thinking about thinking itself.

One possible tool to change education-paradigm, renew our thinking about ICT, about ICT education and thinking itself and to motivate kids in ICT and STEM education is the international Bebras challenge. It can be found in more than 50 countries over the world and plays a significant role in the education system of most countries.

Some aims of this initiation is to move the ever-changing paradigms of education towards a more innovation-driven and sustainable development and to point out the importance of ICT education and express the necessary role of it in everyday life, as well as how specialists use ICT skills in different areas of works.

This study focuses on Bebras background and the workflow, its changes in the Hungarian Bebras Challenge, the experiences and results of competitions in the last 5 years and the extension-activities.

**Keywords:** Computational thinking · ICT · Computer science · Bebras

## 1 Introduction

The significant role of Information and Communication Technologies (ICT) in everyday life could change concepts about skills, education and learning [1–3].

The changing definitions about necessary ICT skills (from digital fluency to computational thinking) shows that they are more about thinking [4] and expressing yourself, exploring the diversity of computers and yourself, involving external representation of problem solving processes, and reflecting on your own thinking – and even to think about thinking itself [5].

### 1.1 ICT, CT and Education

The ICT and Computational Thinking (CT) skills have gained a Life-Long Learning (LLL) and Life-Wide Learning (LWL) aspect while also help managing knowledge


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transfer for educational purposes; moreover, they appear to play a significant role in future employment [6]. Therefore, they should be taught at the earliest possible stage; however, the rate at which education changes shows that school systems have problems adopting these new concepts [1, 2].

The necessary role of applicable knowledge is becoming trivial [7]. The education system - including schools especially - cannot adapt to the pacing of society's changes, and that of technological environment. On the other hand, a deeper understanding and acquiring specific elements is required to automate knowledge transfer, that is the application of knowledge in new and unknown circumstances [8, 9].

Due to the lack of proper definition and the complexity of Computational Thinking (CT), we distinguish three main trends in its measurement and improvement. The first guideline focuses on specific parts such as Algorithmic Thinking or Problem Solving, perhaps not even under the aegis of CT [8, 10–12]. Instead of Algorithmic Thinking, Wing uses the expression Heuristic Thinking and determines CT to be the collection of skills such as "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" [4].

The second frontier opens up by programming and simulation games, among which we may find some new innovations by designing frameworks and integration of already existing applications [13–15].

The third approach is shifting towards specific activities without programming or even computers [16–19].

Even though we happen to differentiate between different agents of thinking and assume that they may alter independently from each other, they can also develop with interactions [8]. While attempting to merge these various cognitive regions, one must agree that "today's schools need to prepare children for problems that we do not even know the existence of" [20].

### 1.2 ICT in the Hungarian School System

In the Hungarian school system informatics education in general faces at lack of necessary support. In the curriculum, public high schools have a single lesson weekly, and that only in the first school year. Apart from the preparation for ECDL and national exams, which are not only the main educational program but generally also the expectation of parents, every other skill mentioned in the latter chapter is either integrated to other subjects or not taken notice of.

University students have little knowledge about Computer Science (CS) and how widespread informatics has become lately. In order to ensure a proper training on prospective expectations for succeeding in modern societies, workplaces and other aspects of life, the earliest possible start of ICT education cannot be overemphasized [7].

Although there are many competitions in programming – considerably because the highly-motivated kids already find more fun in ICT and enjoy solving problems and creating programs by themselves – Hungary (among other countries) struggles to offer motivation in such a competition in general. As mentioned earlier, one of the main reasons is that teachers and competitions usually narrow CS down to programming and using ICT-devices, thus placing CT commonly out of sight.

## 2 Bebras - The International Challenge

As Dagiene and Futschek [21] summarize Bebras ("beaver") idea comes from Lithuania and is an "informatics education community-building model", an initiative to promote CS and CT among school students. It is an international informatics challenge and can be found in many countries all over the world. It plays a significant role in changing the education paradigm and reform, and renewing our thinking about ICT, ICT education and thinking itself.

The main goals are (1) to motivate and interest kids in CS topics, (2) to motivate them to learn about CS more deeply and (3) to promote algorithmic thinking, problem solving and other parts of CT.

The challenge is designed to promote CS to schools by solving short concept-based tasks.

## 3 Bebras in Hungary

### 3.1 Aims

The first Bebras challenge ("Hód" in Hungarian) was organized in Hungary in 2011. The main goals of the Hungarian organizers are to

- show how big, interesting and colorful the CS world is;
- motivate children to be open to CS, problem solving and thinking;
- help teachers make informatics education more colorful and understandable;
- give ideas to teachers for school and after-school activities;

Of course, we support and follow the main Bebras aims and goals, and use and prepare tasks that require no previous knowledge of ICT or CS, "but are clearly related to CS concepts and require computational thinking skills in information representation, discrete structures, computation, data processing, as well as algorithmic concepts" [22].

### 3.2 The Competition

Kids from several levels and kinds of schools in the Hungarian school system may participate – from primary education through elementary schools to secondary education with secondary grammar, technical and vocational schools, too (Table 1).

In the Hungarian contest, we classify tasks by age groups and categories:

**Table 1.** The Bebras competition in the Hungarian school-system

| Categories | Ages | Primary education | Secondary education |
|---|---|---|---|
| Little beavers | 9–10 | 4th class years | |
| Benjamins | 10–12 | 5th–6th class years | |
| Kadets | 12–14 | 7th–8th class years | |
| Juniors | 14–16 | | 9th–10th class years |
| Seniors | 16–18 | | 11th–12th class years |

In each category, the participants have 45 min to solve tasks online, based on the length of a lesson in the Hungarian school system.

Kids have 10 tasks as “little beavers” and 18 tasks in the other categories. We split tasks by difficulty into three groups (easy, medium and hard) based on difficulty-sorting of International Bebras Workshop.

Students may participate in the whole Bebras Week at a pre-registered time. We limit only by class sections: they need to solve tasks at the same time. So students can participate in school time, in one lesson.

To prevent cheating, the answers are mixed up, but the tasks are always in the same order according to their difficulty. Participants can switch between tasks while they compete, but they get the easiest tasks first and the hardest tasks last.

We use positive points initially for each student because wrong answers mean negative points. This way, we provide more feelings of success, since the result is always non-negative. For explanatory purposes only, let us say kids start from 100 points and they lose 10 points if they answer one question wrong. This way, answering everything wrong means zero points.

### 3.3 Platform

In the Hungarian contest we use an online, self-developed platform. Because of our primary desire – to “give” Bebras to every child – it was necessary to create a fast system that can be used in every school in Hungary. We need to provide low internet and CPU usage.

The children need only a browser and internet connection. The tasks are prepared as a multiple choice test, usually with one right answer out of four.

The students are pre-registered with a 15-min limit for logging in. The teachers have access for registration and they can change the beginning time before starting the competition. With the help of this kind of installment, we have managed to gather many teachers as supporters and his led to an exponentially rising number of participants. Details are discussed below in Sect. 5.

## 4 Tasks

Pohl and Hein [23] and Dagiene and Stupuriene [24] summarized the task development process that is also in use in Hungary.

Every country sends 10–12 tasks for the International Bebras Workshop where the organizer countries fill a task pool with qualified tasks translated into English. Developed ideas and tasks from Hungary are created mostly by students at Eötvös Loránd University. In teacher trainings, students are requested to be an active part of the competition and the post-competition activities.

After the international workshop was held each national Bebras group choose tasks and prepare them to their own contest.

Hungary participates in the D-A-CH-U (Germany, Austria, Switzerland and Hungary) meeting that is a second round for the German-language countries to choose and prepare tasks. The Hungarian contest is then based on the tasks discussed there.

This preparation not only consists of translation but rather transfer to one's language, culture, system and school-specific possibilities.

In Hungary, we prefer the tasks that have a good background-idea and can be attached to CS and to a real situation of everyday life because this way pupils might better grasp the essence of each problem.

We mainly select tasks about problem solving, algorithmic thinking and data structures, but every year we use some in the "social, ethical, cultural, international, legal issues" category, as well [25]. It is very important for an exercise to have a good and stable informatics background to offer latter use in CS school lessons and past school activities.

We do not implement interactive tasks, as we would not intend to put schools at a disadvantage - based on minimal ICT. The multiple choice test outline requires well-thought-out wrong choices, since we analyze the thinking strategies that lead to a specific (wrong) answer.

## 5 Research and Results in Hungarian Bebras

### 5.1 Participation

In the first contest (in 2011), there were 1911 students from 24 schools in two categories. In 2016, 18046 students participated from 168 schools in five categories. Figure 1 illustrates this growth.

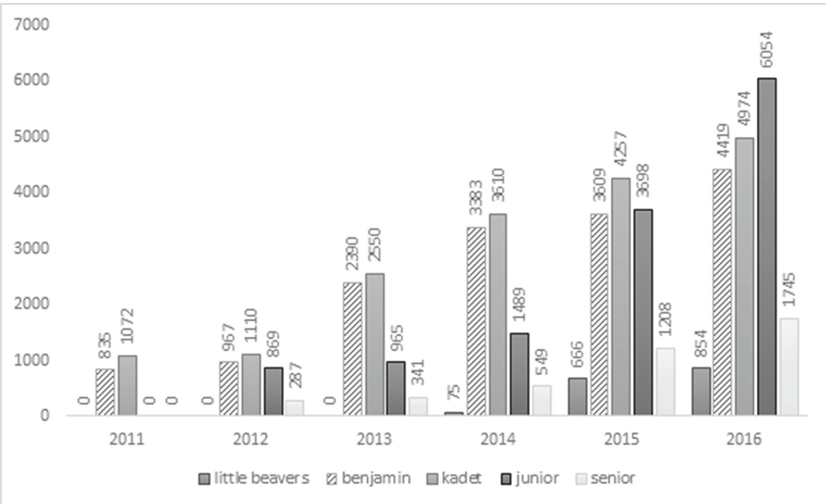


**Fig. 1.** Number of participants on the annually organised Bebras challenge in Hungary

The number of girls and boys were nearly the same in each category. The biggest difference is in the "senior" (oldest) category every year, but at least 20% for boys. The similarity between the number of participants in the two genders is unusual to the common ICT contests but it can be reasoned as we target teachers and suggest involving every student not only the motivated ones. The significant detail is that boys tend to be seen as more into informatics [26] and many contests and other ICT programs struggle with pulling in girls.

The participants of the contest arrive from across the whole country, although more schools attend from the capital and western regions. The map (Fig. 2) shows that several Hungarian-language schools outside Hungary join the initiation. We need to take into consideration whether these schools got the opportunity to get the questions from or applied for the national challenge held in their country, since either would make the contest unfair.

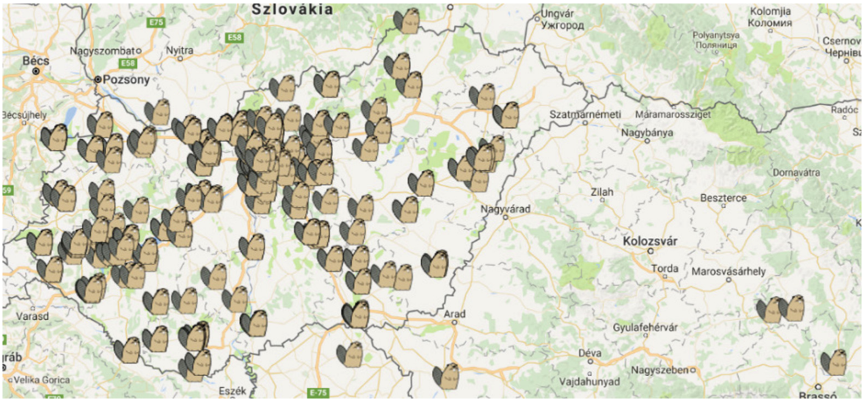


**Fig. 2.** Participants of Bebras challenge in Hungary in 2016 (1 beaver represents 1 school)

### 5.2 Surveys for Innovation

Every year, we analyze the success of the Hungarian contest in many aspects.

We organize a "party" annually for participants where they can give feedback. We have another platform via email, and on one of the biggest Hungarian informatics teacher conferences, too. We collect this feedback and use it principally for improving our platform and using it as concept-element for developing the contest in the next year.

#### 5.2.1 Difficulty of Tasks

For the basic analyses of difficulty, we use the ConQuest [27] IRT program to analyze the results on the competition. The applied model is a generalized form of the Rasch model, a mixed coefficients model. We analyze the tasks and the success of tasks using anchor item.

On the item/person analyses on tasks can be seen that the difficulty was nearly between −2 and +2 logit. There are some "easy" tasks that are harder than "medium" tasks but usually the harder tasks are located on the top and the easier on the bottom. According to the item/person analyses the difficulty levels of the items fit to the students' ability level.

To study the difficulty of tasks more in-depth, we ask the following questions: What makes a question difficult? Is there any influence with the social background or education? What kind of questions are difficult for Hungarian schoolchildren? Can we use "wrong" answers to define difficulty or detect typical bad thinking strategies?

### 5.2.2 Background Questionnaire

In 2013, we prepared a background survey [28] to depict the most influential factors of successful participation and find answers to the questions we asked ourselves.

We asked kids about the possibilities and habits of using ICT tools (computers, mobile phones, tablets) inside and outside their schools. Our questions focused on frequency, contents and parent control.

In the first year of our monitoring, nearly half of the participants answered our background questionnaire ($N = 6246$; $N_{5,6} = 2390$, $N_{7,8} = 2550$, $N_{9,10} = 965$ and $N_{11,12} = 341$). The difference between the number of girls and boys was again not considerable.

One of our results was that participants rarely (50% never as opposed to 10% usually) use ICT tools in learning processes – neither inside the school, nor outside or at home. They use them for chatting, browsing information (such as timetables, programs, …) and listening to music or watching films.

There seems to be only a low correlation between the number of tasks solved correctly and that of entries in earlier Bebras challenges ($r = 0.44$, $p = 0.02$), conducted over the whole sample.

With other parameters, we could not find any correlation between the achievements (grades) in school, the number of ICT tools, the frequency and the content of using them and the control from parents on use of such devices, however we insist on carrying out such researches with increasingly better detailed and more differentiated questions.

## 6 Perspectives - The Bebras Expansion

Over the past few years, gamification has gathered a significant role as an enhancement to attraction for a wide scale of marketing and educational purposes [29]. The invocation of game-like experiences allows the audience to dive deep into a certain topic without obligatory commitments and thus builds intrinsic motivation [30].

Today's demand for higher literacy - involving computer literacy - skills and critical thinking [31] has led us to form a narrative-centered environment that focuses on cultivating one's creativity while also developing problem solving skills. Below are two initiations described that not only provide activities for students but also provide support for teachers who affiliate with computer science and edutainment as a whole.

## 6.1 Immersive Narration

The Hungarian Bebras Committee works to involve pupils into an ever-expanding universe of Bebras ("Hódiverzum", or "Beaverld") by leading them to create short stories that process Bebras tasks. We are developing a platform in order to maintain children's access to the tasks in such a way that they can choose which one they would like to animate. For a more personal approach, we have created a group of characters that would appear in these stories.

To begin with, we are guiding children with story examples and specific introductions of the characters so they get a grasp on storytelling and become familiar with the problems presented. As each character has unique skills, one should decide, who fits better for solving a certain problem. As a remark, we assume that children may have affection for some of the characters so we publish them one by one with a profile consisting of family relations (inside the Beaverld), personal report, outlook and a badge.

Beyond this stage, our intention is to compose the digital version of the stories including multimedia elements to further enhance the immersion effect that the cooperative creation of worlds like Beaverld offers [32].

## 6.2 Escape from the Empire of Cyber-Lynxes

Since gamification elements appear in many forms of education [33], the effects on learning has been observed in several papers. Aside from the positive outcomes, they also encourage an increased level of competition [34], which is supposed to be a downside effect; however, we look forward to turning it on our advantage by creating a cooperative escape room consisting mainly of Bebras tasks implemented in augmented reality.

The concept is that some beavers got trapped in a room in the territory of cyber-lynxes (the digital adversaries of bit-beavers) and they need to cipher passwords and understand the coding system in order to send a message for help. We designed two versions of the escape room, one of which is exclusively for internal use (organized at the Hungarian Bebras Headquarters at Eötvös Loránd University), while the other is a low-cost form that can be held in any (class)room with little need for devices that may be difficult to acquire, such as robots, sensors and other Internet of Things (IoT) devices. We settled the group size in a first approach as three to five students.

In addition to the drifts of narration mentioned above, the story allows us to drop in unexpected events in order to help children who got stuck at stages of tasks while also granting the potential of adding some more complicated exercises to experts. Throughout the activity, participants have the opportunity to carry out tasks together, but there are some problems that are best to be solved simultaneously, so they also need to work separately. There are also a few examples for exercises that require other ones to be done in advance, thus training the scheduling and sharing skills.

The complexity of the escape room and in a much wider aspect, the Beaverld concept, inclines us to conduct new researches on children's needs, affection and requisition for innovation and possible support. Even though we might face demands and barriers that are yet unseen, our aim remains to narrow the gap between entertainment and education for a modern and amusing learning experience.

### 6.3 Cooperation with Other Contests

As the popularity of the Bebras challenge is rising, with a total number of 1,610,000 participants in 2016, one may consider the possibility of somehow merging its aims (ICT education and computational thinking) with other parts of studies e.g. mathematics.

Today's largest mathematical competition, The Mathematical Kangaroo, may provide a vast amount of tasks to be implemented in the same manner as we introduced in this heading. It is yet unclear whether it would popularize problem solving even more or dredge up such problems as math anxiety to the surface and deter some people from getting involved [35].

Among many others, there is an annual Hungarian math competition called Medve Matek ("bear math") that aims to familiarize pupils with mathematics while having fun outside, which may also offer possibilities to enrich our growing mindset of development in a highly effective and more advanced manner.

## 7 Conclusion and Plans

The challenge discussed is growing rapidly all over the world, and other Bebras activities are setting root. This paper has explained how the Hungarian contest works by expressing the viability and significance of ICT education, edutainment while presenting the Bebras Challenge in general and also introducing new ideas for further development besides research purposes and aims.

In the future, the Hungarian contest could gain even higher popularity and we also propose to change the thinking of teachers and students about CS and ICT tools.

Next year we intend to organize a new background-questionnaire part and analyze the results in the dimension of years and prepare a longitudinal research about tasks and participants on Hungarian contests and the expansion of the Bebras challenge. The new extensions such as the escape room is about to go under a thorough survey to recognize the effects and potential and even to look for correlation between the results of children in the escape room and on the challenge.

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## References

1. Csapó, B.: A tudáskoncepció változása: nemzetközi tendenciák és a hazai helyzet. Új Pedagógia Szemle **2**, 38–45 (2002)
2. Casey, P.J.: Computer programming: a medium for teaching problem solving. Comput. Sch. **XIII**, 41–51 (1997)
3. Molnár, G., Kárpáti, A.: Informatikai műveltség. In: Csapó Benő: Mérlegen a magyar iskola. Nemzeti Tankönyvkiadó, Budapest, pp. 441–476 (2012)
4. Wing, J.M.: Computational thinking. Commun. ACM **49**(3), 33–35 (2006)
5. diSessa, A.: Changing minds: computers, learning, and literacy. MIT Press, Cambridge (2000)
6. Dinevski, D., Kokol, P.: ICT and lifelong learning. Eur. J. Open Distance E-Learn. (2005). http://www.eurodl.org/materials/contrib/2004/Dinevski.html. Accessed 18 May 2017
7. Vujovic, P.: Improving teaching skills: from interactive classroom to applicable knowledge. Adv. Physiol. Educ. **40**(1), 1–4 (2015). https://doi.org/10.1152/advan.00139.2015
8. Adey, P., Csapó, B.: A tudományos gondolkodás fejlesztése és értékelése. In: Csapó Benő és Szabó Gábor (ed.) Tartalmi keretek a természettudomány diagnosztikus értékeléséhez, Nemzeti Tankönyvkiadó, Budapest, pp. 17–57 (2012)
9. Csapó, B.: Természettudományos nevelés: híd a tudomány és a nevelés között. Iskolakultúra **9**(10), 5–17 (1999)
10. OECD: PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science, vol. I. OECD Publishing, Pisa (2010). OECD, Paris
11. Csapó, B.: A tanulás dimenziói és a tudás szerveződése. Educatio **2008**(2), 107–217 (2008)
12. Chen-Chung, L., Yuan-Bang, C., Chia-Wen, H.: The effect of simulation games on the learning of computational problem solving. Comput. Educ. **57**, 1907–1918 (2011)
13. Brennan, K., Resnick, M.: New frameworks for studying and assessing the development of computational thinking. In: AREA (2012)
14. Brennan, K.: Creative computing: a design-based introduction to computational thinking (2011). http://scratched.media.mit.edu/sites/default/files/CurriculumGuide-v20110923.pdf
15. Aiken, J.M., Caballero, M.D., Douglas, S.S., Burk, J.B., Scanlon, E.M, Thoms, B., Schatz, M.F.: Understanding student computational thinking with computational modeling. In: PERC Proceedings (2012)
16. Bell, T., Witten, I.H., Fellows, M.: Computer Science Unplugged (2010)
17. Dagiene, V.: Information technology contests – introduction to computer science in a attractive way. Inf. Educ. **5**(1), 37–46 (2006)
18. Pluhár, Zs.: Bit HÓDítás. In: Ollé János (ed.) 4. Oktatás-informatikai konferencia: Tanulmánykötet. Budapest. ELTE Eötvös Kiadó, pp. 187–191 (2012)
19. Cartelli, A., Dagiene, V., Futschek, G.: Bebras contest and digital competence assessment: analysis of frameworks. Int. J. Digit. Lit. Digit. Competence **1**(1), 24–39 (2010)
20. Mérő, L.: Maga itt a tánctanár? Kossuth Kiadó, Budapest (2015)
21. Dagiene, V., Futschek, G.: Bebras international contest on informatics and computer literacy: criteria for good tasks. In: Mittermeir, R.T., Syslo, M.M. (eds.) Informatics Education – Supporting Computational Thinking. Lecture Notes in Computer Science, vol. 5090, pp. 19–30. Springer, Heidelberg (2008)
22. Dagiene, V., Futschek, G.: Knowledge construction in the Bebras problem solving contest. In: Conference: Constructionism, 2012 (2012)
23. Pohl, W., Hein, H.W.: Aspects of quality in the presentation of informatics challenge tasks. LNCS, vol. 9378, pp. 21–32 (2015)

24. Dagiene, V., Stupuriene, G.: Bebras – a sustainable community building model for the concept based learning of informatics and computational thinking. Inf. Educ. **15**(1), 25–44 (2016)
25. Dagiene, V., Futschek, G.: Bebras international contest on informatics and computer literacy: a contest for all secondary school students to be more interested in informatics and ICT concepts. In: Proceedings of 9th WCCE 2009, Education and Technology for a Better World, 9th WCCE 2009, Bento Goncalves (2009). ISBN 978-3-901882-35-7, Paper-Nr. 161, 2
26. Sobh, T., Elleithy, K.: Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering (2014). ISBN 978-3-319-06773-5
27. Wu, M., Adams, R.J., Wilson, M.R.: ACER ConQuest: Generalised Item Response Modelling Software. ACER Press, Australia (1998)
28. Pluhár, Zs.: Az informatikai műveltség egyes dimenzióinak mérése. In: Buda András (ed.). XIV. Országos Neveléstudományi Konferencia: Oktatás és nevelés – gyakorlat és tudomány: Tartalmi összefoglalók. Debrecen (2013)
29. Hamari, J., Koivisto, J., Sarsa, H.: Does gamification work? - A literature review of empirical studies on gamification. In: Proceedings of the 47th Hawaii International Conference on System Sciences, Hawaii, USA, 6–9 January 2014, pp. 3025–3034 (2014). ISBN 978-1-4799-2504-9
30. Wu, M.: Gamification 101: the psychology of motivation (2011). https://community.lithium.com/t5/Science-of-Social-blog/Gamification-101-The-Psychology-of-Motivation/ba-p/21864. Accessed 16 May 2017
31. Mort, B.W., Callaway, C.B., Zettlemoyer, L.S., Lester, J.C.: Towards narrative-centered learning environments (1999). https://vvvvw.aaai.org/Papers/Symposia/Fall/1999/FS-99-01/FS99-01-013.pdf. Accessed 16 May 2017
32. Benmayor, R.: Digital storytelling as a signature pedagogy for the new humanities. Arts Humanit. High. Educ. **7**, 188–204 (2008). https://doi.org/10.1177/1474022208088648
33. Wiemker, M., Elumir, E., Clare, A.: Escape room games: can you transform an unpleasant situation into a pleasant one? In: Game Based Learning - Dialogorientierung & spielerisches Lernen analog und digital, Ikon Verlags Gmbh, 2016, pp. 55–68 (2015). ISBN 978-3-99023-411-2
34. Hakulinen, L., Auvinen, T., Korhonen, A.: Empirical study on the effect of achievement badges in TRAKLA2 online learning environment. In: Proceeding of Learning and Teaching in Computing and Engineering (LaTiCE) conference, 21–24 March 2013, Macau, pp. 47–54 (2013). https://doi.org/10.1109/LaTiCE.2013.46
35. Foley, A.E., Herts, J.B., Borgonoci, F., Guerriero, S., Levine, S.C., Beilock, S.L.: The math anxiety-performance link: a global phenomenon. Curr. Dir. Psychol. Sci. **26**(1), 52–58 (2017). https://doi.org/10.1177/0963721416672463

# Self-evaluation of Pedagogical Competencies of Academic Staff in the Context of Career Management

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**Abstract.** The model of Assessment of Academic Staff Work Performance and Feedback has been designed at Tallinn University of Technology (TTU). The model links the main stages of the assessment process from collecting data for compiling a personal portfolio and analyzing personal training needs, to conducting the development and career interview and finalizing with attestation interview. Professional Competencies Self-Evaluation Questionnaire for evaluation of pedagogical/professional competencies of academic staff has been designed based on the model of IGIP competencies of engineering educators' obtained by passing the IGIP curriculum. The main emphasis of this paper lies on training needs analysis pilot survey, carried out by implementing Professional Competencies Self-Evaluation Questionnaire for academic staff members in TTU in March 2017. The results of the analysis of the pilot survey are presented in the paper.

**Keywords:** Training needs analysis · Self-evaluation · Career management Attestation

## 1 Introduction

Global trends such as educating a growing number of students, increasingly multicultural and heterogeneous student groups, the need to lengthen working careers as well as to increase the pace at which academic studies are completed, have imposed new challenges for universities and their teaching staff. This has increased the importance of educational or pedagogical training for university lecturers and professors in recent years [1]. There are different kinds of conceptualizations for professional development. According to an Organization for Economic Cooperation and Development (OECD) report, effective professional development can be seen as an on-going process, which includes training, practice and feedback and adequate time and follow-up support [2].

In the field of educational development, many different concepts have either been used interchangeably or in order to focus on different aspects of development; such concepts include, for example, faculty development, professional development, academic development, curriculum development and organizational development [1].


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Scientific Management sought to improve workplace efficiency, reduce the need for human cognition, and carefully prescribe human work behaviors. A steady progression of the transfer of responsibility for learning, from the trainer to the individual learner of today, can be seen [3].

Training needs reflect current or anticipated deficiencies in determinants of performance that can be remedied, at least in part, by a training intervention. Training needs exist in a number of contexts. For example, current jobholders may be deficient in terms of their performance, and the primary purpose of training is to remedy the deficiency. In a different context, if eligibility for promotion is a function of high performance on particular performance components, training on the determinants of those performance components may be offered to, or sought by, anyone wanting to be considered for promotion.

Training needs assessment has three major steps. The first step describes the factors that comprise effective performance; the second step includes specifications of the determinants of performance on the factors, and identification of the performance determinants that would benefit from a training intervention. The third step focuses on individuals, or on forecasted future training needs for everyone in an occupation.

The aim of this article is to provide an overview of the model of Assessment of Academic Staff Work Performance and Feedback at Tallinn University of Technology (TTU) and describe the process of identification of personal professional development needs of academic staff members. The term “academic staff member” means a person holding an academic post under an employment contract including all official ranks of professors, lecturers, researchers, and teachers.

The main emphasis of this paper lies on training needs analysis pilot survey, carried out by implementing Professional Competencies Self Evaluation Questionnaire for academic staff members in TTU in March 2017.

## 2 Approach

The Regulation of Academic Career Management established in TTU in January 2017 [4] sets rights and obligations of academic staff members, job descriptions of academic staff members, procedures for filling academic posts and assessment of work performance and feedback. The purpose of the assessment of the work performance of an academic staff member is to assess the work results and eligibility of academic staff and to provide them feedback as well as to motivate them to improve the academic performance of the university. Assessment of work performance must support the career perspectives and professional development of the academic staff.

According to the Regulation of Academic Career Management [4] the competencies of academic staff are the following:

- Research competency;
- Teaching competencies – pedagogical, didactic, subject related and evaluation management competencies;
- English language proficiency;
- Educational technology competencies;

- Other competencies – organizational, managerial, communicative and social skills.

Work performance of academic staff is assessed and feedback is provided:

- In the course of a development and career interview;
- At the time of attestation.

The attestation committee shall assess compliance of the employee's work performance and his or her compliance to professional standards based on the relevant job description set out in regulation, the expected work output and the performance indicators set out in the academic evaluation matrix and the following documents:

- A review of the work performed in the previous evaluation period prepared by the employee and his or her assessment of his or her work performance;
- The results of the development and career interview concerning the period subject to evaluation;
- The academic portfolio;
- Students' feedback on teaching and courses in the previous period subject to evaluation;
- Other materials considered necessary by the employee or the attestation committee.

The Academic Evaluation Matrix established at TTU in January 2017 [5] is a tool for evaluation of academic competencies and performance. The matrix is used for making decisions concerning academic posts. The matrix includes descriptions of eleven academic competencies and performance levels on a 9-level scale. In order to determine the level required from a candidate to a specific post or from a person filling the specific post, the general job descriptions of the Academic Career Management and the goals and expected work results laid down in the job description of the specific academic post and the personal job description of the academic staff member shall be taken into account.

Types of academic activity are the following [5]:

- Publication and number of citations;
- Activity and success in applying for competition-based financing;
- Cooperation with the business and public sector;
- Innovation and inventing;
- Supervision;
- Teaching;
- Development of studies;
- Professional activities;
- Organization of research and education;
- Public engagement;
- Acknowledgements.

The Task Force under Personnel Office Staff Development and Mobility Centre has developed the model of Assessment of Academic Staff Work Performance and Feedback.

The model links the main stages of the assessment process from collecting data for compiling a personal portfolio and analyzing personal training needs, conducting the development and career interview and finalizing with attestation interview (Fig. 1). Both qualitative and quantitative data will be collected in order to get input for academic staff member's training needs assessment.

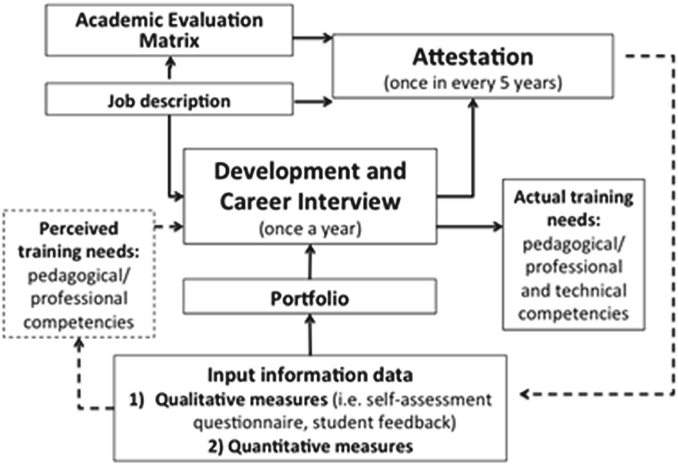


**Fig. 1.** Assessment model of academic staff work performance and feedback (Source: compiled by the author)

In order to get relevant information and receive data for performance assessment two kinds of measures will be implemented:

1. Qualitative measures are:
   - Self-assessment on pedagogical/professional competencies;
   - Student feedback;
   - Continuous education student feedback.
2. Quantitative measures are as following:
   - Statistics on attendance in trainings and development programs;
   - The number of supervised theses and defended academic degrees;
   - The level of scientific publications and number of citations;
   - Attendance in research and related development activities;
   - Other activities related to main functions.

The personal academic portfolio is one of the self-assessment forms [5], which includes both quantitative and qualitative measures of academic staff member work performance. Portfolio includes data from different sources e.g. self-assessment on pedagogical/professional competencies, student feedback, attendance in research and related development activities, networking, international and internal mobility etc. The aim of the personal portfolio is to submit evidence of professional and pedagogical competencies. Portfolio is the main source for carrying out evidence-based development and career interview and attestation. Portfolio is to be developed electronically and consists of four chapters and appendixes. At TTU chapters of the portfolio are as following [5]:

1. Pedagogical activity;
2. Academic mastery;
3. Management and leadership;
4. Other relevant information.

Curriculum of International Society for Engineering Pedagogy (IGIP) serves as the basis for pedagogical continuing education of academic staff in TTU [6].

Section 2 is based on the Professional Competencies Self-Evaluation Questionnaire (PCSQ) results Questionnaire has been designed based on the model of IGIP competencies [6] and adjusted for evaluation of the pedagogical/professional competencies of academic staff members at TTU in February-March 2017.

As the result of completing the questionnaire the perceived training and self-development needs of evaluate will be clarified, but still the input from other sources like feedback from supervisor, students and colleagues is needed. All evidence and findings will be discussed between the supervisor and his/her subordinate during the Development and Career Interview, and at the end of the interview actual training and development needs will be identified and agreed.

## 3 Pilot Survey

Pilot survey has been carried out by implementing Professional Competencies Self-Evaluation Questionnaire for academic staff members at TTU in March 2017.

Professional Competencies' Self-Evaluation Questionnaire for evaluation of pedagogical/professional competencies for academic staff has been designed based on IGIP model of competencies of engineering pedagogy obtained by passing the IGIP curriculum for engineering educators [6].

The questionnaire was designed for self-evaluation of the following competencies:

- Pedagogical, Social, Psychological and Ethical Competencies;
- Didactical Skills and Subject Expertise;
- Evaluative Competencies;
- Organizational/Management Competencies;
- Communicative and Social Competencies;
- Reflective and Developmental Competencies.

The compiled questionnaire included 55 different questions for assessment of above listed competencies. For responses a *Likert*-type forced choice scale has been chosen as the most widely used basis for surveys. The questions were presented as statements. A response scale used had the choices from "totally disagree" up to "fully agree". Respondents had a possibility to leave a comment at the end of the analysis of each competency and assess their need for continuing education for development of assessed competencies.

A sample of 55 technical teachers (N = 55) evaluated their training needs in the pilot survey, 49% of respondents were female and 51% male teachers. All the respondents had been accepted recently to the curriculum of a technical teacher education based on IGIP curriculum and assessed their competencies before the courses. 12% of the respondents had acquired vocational education in specialty they teach, and 13% had technical education on secondary level, 27% of respondents had bachelor degree, 44% master degree, and 4% doctoral degree in engineering.

According to the results of the survey 7% of respondents had been working as technical teachers for more than 20 years, 9% had been teaching for 11–20 years, 16% had been teaching for 6–10 years, 49% for 1–5 years, and 19% of respondents were just planning to start teaching after taking the courses.

### 3.1 Self-evaluation of Pedagogical, Social, Psychological and Ethical Competencies

This section of the questionnaire consisted of 13 statements assessing the possession of following sub competencies: creating positive learning environment (50% of respondents fully agreed), preferring democratic leadership style (24% of respondents fully agreed), treating students as equal partners (50% fully agreed), relying on the principles of group dynamics (26% fully agreed), valuing students' creativity in problem solving (80% fully agreed), promoting students' active contribution to learning (54% fully agreed), taking account of the key principles of learning theories in teaching (15% fully agreed), teaching critical thinking (30% fully agreed), supporting the development of students' professional identity (48% fully agreed), using student motivation techniques in teaching (28% fully agreed), taking account of ethical values of different cultures (68% fully agreed), behaving in compliance with the general principles of the teacher's professional ethics (82% fully agreed), ensuring dignified treatment of all parties in case of conflicts (72% fully agreed).

Based on the analysis of self-evaluation results, nearly 51% of respondents stated their need for essential training in order to improve their pedagogical, social, psychological and ethical competencies, about 42% of respondents decided that they need training in some competencies only, 7% of respondents decided that they do not need any continuing education at all.

### 3.2 Self-evaluation of Didactical Skills and Subject Expertise

The section included 14 different statements assessing respondents' didactical skills and subject expertise. IGIP assumes that persons attending teacher education based on IGIP curriculum already possess high expertise in the field and subject they teach.

The following competencies were assessed: planning and conducting studies in accordance with the principles of (engineering) pedagogy science (13% of respondents fully agreed), setting clear learning goals and defining relevant learning outcomes (30% fully agreed), planning for teaching by using an appropriate didactic model(s) (13% fully agreed), compiling and structuring methodologically effective learning materials (21% fully agreed), taking account of students' differences in teaching (prior knowledge, experience, different learning styles and other individual differences) (30% fully agreed), selecting suitable teaching aids to support students in their achievement of learning outcomes (33% fully agreed), informing students about the learning outcomes, assessment methods and requirements at the beginning of the course (56% fully agreed), selecting the most appropriate teaching methods (30% fully agreed), using illustrative and visual aids (59% fully agreed), using contemporary ICT tools in teaching (44% fully agreed), creating interdisciplinary connections in the teaching process (22% fully agreed), integrating professional, technological and pedagogical innovations into learning process (31% fully agreed), using active learning strategies (31% fully agreed), using e-learning to support classroom teaching (20% fully agreed).

According to the decision of respondents on the need for continuing education for development of their didactical skills and subject expertise, about 45% of respondents stated that they need essential continuing education, 49% need training for development of some competencies, 4% decided that they do not need any continuing education, and about 2% could not assess their need for continuing education.

### 3.3 Self-evaluation of Evaluative Competencies

This section consisted of 6 statements assessing respondents' following evaluative competencies: possession of an overview of the effectiveness of different assessment methods (9% fully agreed), defining adequate assessment criteria (17% fully agreed), using appropriate motivating assessment methods to verify achievement of learning outcomes (20% fully agreed), following students' progress in the learning process (52% fully agreed), providing constant feedback to students during teaching (43% fully agreed), providing advice and guidance to students for their self-analysis (26% fully agreed).

According to the self-analysis, 51% of respondents need training in some evaluative competencies, 36% need essential training, and 11% of respondents decided that they do not need any continuing education; about 2% of respondents could not assess their need for continuing education.

### 3.4 Self-evaluation of Organizational/Management Competencies

The section included 6 statements assessing the respondents' following organizational/ management competencies: creating or organizing a supporting learning environment (28% of respondents fully agreed), efficient time management (27% fully agreed), possessing very good project planning and implementation skills (23% fully agreed), possessing an overview of legal acts regulating education (7% fully agreed), following quality assurance principles in teaching (9% fully agreed), solving unforeseen situations creatively (44% fully agreed).

About 45% of respondents have stated their need for training in some organizational/ management competencies, 45% decided that they need essential training, about 6% feel they do not need any continuing education, and about 4% could not assess their need for continuing education developing their organizational/management competencies.

### 3.5 Self-evaluation of Communicative and Social Competencies

The section included 7 statements evaluating respondents' following communicative and social competencies: working in interdisciplinary team (13% of respondents fully agreed), applying the principles of clarity and intelligibility in teaching (26% fully agreed), discussing different teaching principles with colleagues (28% fully agreed), participating in international cooperation networks (20% fully agreed), giving effective presentations (15% fully agreed), possessing very good academic writing skills (6% fully agreed), possessing very good communication skills (15% fully agreed).

According to the self-analysis, about 55% of respondents need training for the development of some communicative and social competencies, 36% need essential training, and about 6% of respondents could not assess their need for further continuing education; about 6% do not need any continuing education fir the development of their communicative and social competencies.

### 3.6 Self-evaluation of Reflective and Developmental Competencies

This section includes 9 statements evaluating the following reflective and developmental competencies: integrating engineering specialty innovations into teaching (36% of respondents fully agreed), integrating pedagogical innovations into teaching (19% fully agreed), analyzing systematically one's activities as a teacher (30% fully agreed), analyzing and assessing one's skills and knowledge in engineering specialty subject(s) taught (36% fully agreed), asking for students' feedback (28% fully agreed), taking account of the feedback for making relevant changes in teaching (33% fully agreed), valuing collegial feedback (54% fully agreed), setting goals for self-development (56% fully agreed), developing teaching philosophy statement (51% fully agreed).

According to the data on self-analysis, 53% of respondents need continuing education in some competencies, 30% decided that they need essential training, 9% decided that they do not need any continuing education, and about 8% of respondents could not assess their need for continuing education for development of their reflective and developmental competencies.

## 4 Discussion and Further Development

IGIP curriculum has served as the basis for pedagogical continuing education of academic staff in TTU. Curriculum in the amount of 25 ECTS has been designed in 2012 for pedagogical training of TTU staff. The curriculum has been accredited by IGIP since 2013 and accordingly to IGIP principles affords necessary competencies for effective teaching engineering. Graduates of the curriculum have the possibility to apply for the qualification of International Engineering Educator ING.PAED IGIP.

As a rule, the participants of the pedagogical continuing education have to evaluate their competencies before and after the training. The present analysis has been developed based on the self-evaluation process carried out by the beginners of the course.

The aim of the survey has been to pilot the compiled Professional Competencies Self Evaluation Questionnaire for testing its functioning as a self-evaluation tool.

55 respondents have accurately evaluated their competencies and training needs in 6 different fields of competency.

Survey outcomes indicate the strong need for continuing training in some didactical skills and evaluative competencies, i.e. implementing basic principles of engineering pedagogy, developing didactical models when planning classes, applying interdisciplinary approach, practicing efficient and effective evaluation methods and guiding students in self-analysis. Skills in project management, implementing principles of TQM in teaching-learning process and presentation skills are to be improved as well as self-reflection and self-evaluation skills.

Strong orientation on self-development is evident (see Fig. 2). As it could be seen in Fig. 2, the majority of respondents (55%) need training in some communicative and social competencies, in some reflective and developmental competencies (53%), in some evaluative competencies (51%), and in some didactic and subject-related competences (49%). More than a half of respondents need essential continuing education for the development of pedagogical, social, psychological and ethical competencies (51%), but also essential training is needed for the development of didactic and subject-related competencies (46%), and for the development of organizational/management competencies (45%).

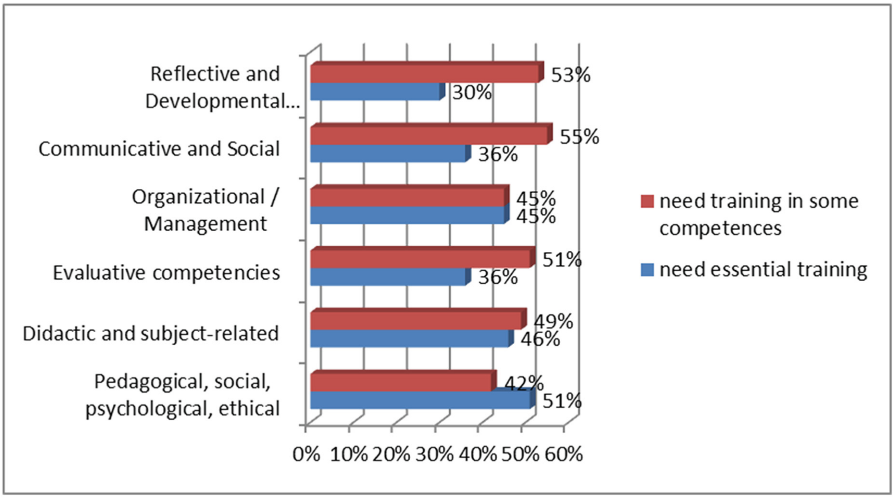


**Fig. 2.** The need for continuing education for development of pedagogical competencies

The analysis of the pilot survey has proved that the designed Professional Competencies Self Evaluation Questionnaire is reliable and may be used as the basis of the assessment of academic staff members' training needs.

Further developments include the research of TTU academic staff's self-analysis in September 2017 and fostering the process of portfolio design at TTU. After the research at TTU the results will be analyzed and results will be published informing also about how this program could be replicated elsewhere or how it might otherwise be applied at another institutions.

## 5 Conclusion

Traditional faculty performance appraisal has developed a reputation for weighing research too heavily, not taking account of pedagogical competencies of the faculty. Pedagogical competencies are of high importance in the faculty review process, including tenure and promotion decisions. Pedagogical competencies are factor of success in facilitating students' learning. Universities could plan continuing education of the faculty according to the perceived and actual training needs of academic staff.

Students' feedback, teaching portfolio compilation and self-evaluation are just some of the most powerful instruments of the evaluation of teaching, still the input from other sources like feedback from supervisor, students and colleagues is needed. All evidence and findings should be discussed between the supervisor and faculty member subordinate during the Development and Career Interview and at the end of the interview actual training and development needs will be identified and agreed.

The model of Assessment of Academic Staff Work Performance and Feedback has been designed at Tallinn University of Technology. The model links the main stages of the assessment process from collecting data for compiling a personal portfolio and analyzing personal training needs, to conducting the development and career interview and finalizing with attestation interview. Professional Competencies Self-Evaluation Questionnaire for evaluation of pedagogical/professional competencies of academic staff has been designed based on the model of IGIP competencies of engineering educators' obtained by passing the IGIP curriculum.

The analysis of the pilot survey results has proved that the designed Professional Competencies Self Evaluation Questionnaire is reliable and may be used as the basis of the further assessment of academic staff members' training needs.

The quality of education crucially depends on the quality of teaching. If we aim to improve the quality of education – we should first and foremost improve the quality of teaching, starting with faculty self-analysis and moving on to other elements of the model of Assessment of Academic Staff Work Performance and Feedback designed at TTU.

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## References

1. Hirsto, L., Lampinen, M., Syrjäkari, M.: Learning outcomes of university lecturers from a process-oriented university pedagogical course. TRAMES **17(67/62)**(4), 347–365 (2013)
2. OECD: The professional development of teachers. In: Creating Effective Teaching and Learning Environments: First Results from TALIS, pp. 47–86 (2009). http://www.oecd.org/berlin/43541636.pdf. Accessed 26 June 2013
3. Kraiger, K.: Looking back and looking forward: trends in training and development research. Hum. Res. Dev. Q. **25**(4), 401–408 (2014). https://doi.org/10.1002/hrdq.21203

4. The regulation of academic career management of TTU, established in January 2017. www.ttu.ee. Accessed 15 May 2017
5. The academic evaluation matrix of TTU, established in January 2017. www.ttu.ee. Accessed 20 May 2017
6. IGIP Curriculum: International Society for Engineering Pedagogy (2017). www.igip.org. Accessed 18 May 2017

# Learning to Program with Lego Mindstorms – Difference Between K-12 Students and Adults

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**Abstract.** In this paper, a workshop that was originally designed for K-12 students as a first introduction into programming by using Lego Mindstorms is conducted on adults coming from different companies. The aim of the study is to compare attitudes and results of adult learners with K-12 students and to see how their interests and understanding of programming concepts differ from the original audience. It is found that the exact same workshop is suitable for older audience and, as expected, the adults are showing slightly better learning outcomes. Using Lego as a tool for teaching is not a problem for adults.

**Keywords:** Lego Mindstorms · Adult education · Programming education
Educational data mining · Lifelong learning

## 1 Motivation

Computational thinking has lately gained a lot of attention. It has been stated that computational thinking should be part of every K-12 student's education. Studying computational thinking has been associated with studying programming. There are many different tools available for teaching programming to K-12 but one of the most popular one has been Lego Mindstorms, mainly because of it's easy to use approach and familiarity to students.

Computational thinking and programming skill are not only important for K-12 students. In modern world, competences covered by computational thinking are useful for everyone – from child to adult. Technology sector is one of the most rapidly changing economies in Estonia and in many other countries. Professionals with engineering skills, computational thinking and ability to navigate the world of technology are needed by many companies. It has been stated that there is a huge gap between available workforce and opened positions in Estonian technology companies. Therefore, more effort has been put into re-training and lifelong learning to make sure employees are matching the pace of changes around them. For many adult learners who are forced to retrain or are in continued professional training, learning programming, engineering competences and computational thinking is taunting. They tend to perceive those competences as hard, themselves too old to gain this kind of novel knowledge or are otherwise reluctant. Therefore, to motivate adult learners, programming and other aspects of engineering could be introduced by using Lego Mindstorms and playful learning situations. On the


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other hand, Legos are considered to be toys and even with K-12 students and some age groups (mostly 13–15 years old), it has been found previously that participants regard Legos as toys and have negative attitude about using Legos in learning context. Therefore, the main research question was if adults have similar problem as some teens with Legos as teaching tool or are they able to submerge into learning without prejudice. Furthermore, the goal was to see if adults have better results than K-12 students and how adults differ from high school students who show best results among K-12.

## 2 Background

The workshop used in this study was originally designed at the start of 2014 for students aged 16–18 to introduce them to programming with Lego Mindstorms robots before they enroll into STEM curriculums in university as a part of the outreach program in Tallinn University of Technology. Within months the teachers were asking university if they could bring younger students to the workshop and therefore from 2014 spring the workshop was open for all K-12 students. A detailed analysis about the effect of the workshop on K-12 students can be found in [1] where it was concluded that two hours with playful situation is enough to give different ages the first connection with programming.

From literature, it can be seen that Lego Mindstorms robots have also been previously used for teaching adult learners. For example Klassner and Anderson in [2] proposed that using Lego robots in Computing Curriculum could be beneficial and motivating for college students. Danahy et al. in [3] offers a review covering over 15 years where Lego robots have been used in real college engineering education process. He also covered many case examples on how different universities have used Mindstorms in both engineering and non-engineering curriculums with large class sizes. Álvarez and Larrañaga [4] studied around 100 students on how using Mindstorms affects programming among first year students. Korkmaz [5] also uses Mindstorms with around 50 students for freshman programming courses. Lykke et al. [6] covers freshman programming courses and Mindstorms in the perspective of motivation. Grandi et al. [7] uses Mindstorms to teach real-time programming and robotics in competition citation. Cuéllar and Pegalajar in [8] covers in detail how Lego Mindstorms were used in intelligent systems course. Kim et al. [9] studies the use of Mindstorms in MSc and early PhD level to teach guidance control and visual tracking.

Sauppé et al. [10] has previously conducted a study on two-day computer science and robotics workshop for ages 9–14 and senior students (age 55 and up) where one of the components was Lego Mindstorms. She concentrates mostly on the challenges of having two very different age groups in a workshop. Gómez has not used Lego Mindstorms but other small robots to teach adults with cerebral paralysis [11].

Grey et al. [12] covers lifelong learning where Lego Mindstorms were used but participants of the study are still undergraduate and graduate students. Leitão et al. [13] also covers lifelong learning in context of Lego Mindstorms with two small groups of teachers and students.

It can be seen that majority of the applications of Lego Mindstorms with older than K-12 students are in higher education, mostly connected with freshman programming courses. No comprehensive study that would compare how K-12 students and adult learners differ when studying programming with Lego Mindstorms could be found.

## 3 Structure of the Workshop

For the current study, two hour intense programming workshops with Lego Mind-storms EV3 kits were developed and conducted [14]. No code was written by the participants. Instead visual programming software offered by Lego was used which “hides” all complexities in programming. Participants only needed to drag and drop blocks and change their modes and parameters in order to solve the task. Majority of the participants worked in pairs. The workshop used simple two wheeled robot with third ball wheel for balance.

Workshop started with a short introduction into robotics, followed by a 30 min period spent on finishing the robot design by adding sensors. Afterwards, a short lecture about programming followed. After the programming blocks were introduced and participants were familiarized with the programming environment, the workshop’s assignment was introduced. It was a simple line following exercise. Robots start to move after a touch sensor has been pushed and use gyro sensor to turn 180°. Then, by using a color sensor, they track the edge of the black line until they reach the finish, marked with yellow as can be seen from Fig. 1. Robots use sound to notify when they have reached the end.

**Fig. 1.** Racing in the end of the workshop

Teams had around 20 min to come up with an initial program and to start doing the test runs. They were then encouraged to try different parameters on blocks which are controlling robot's movement so they could make the robot go faster. By trial and error they changed their program and tried different types of movement programming blocks until they found what they thought was the fastest solution. The programming part of the workshop, including testing, took usually around an hour. Workshop ended with a race between teams – it was not used so much for finding the best team but as to remind them that with two hours they all managed to make a robot move and race.

Feedback about the workshop was collected from the participants about their preferences (before and after the workshop), their previous experience and interests about technology. They also contained a multiple choice questionnaire. In total 15 questions were asked – 8 about programming concepts and 7 about robotic movement. All the blocks used in the assignment were covered, few of them doubled for verification purposes (to identify students who randomly select answers and might have gotten a "right" answer due to luck). Choices for each question contained multiple "correct" answers with few obviously wrong ones. The choices were designed so that some reflected the understanding of a block in current task's context while others reflected a more comprehensive understanding of the programming concepts. An option "do not know" was also offered. There were few open ended questions and comment section.

## 4 Participants

Within last 3 years, more than 2000 students from K-12 schools have attended the workshop. During that time, more than 700 adults have also participated in the same workshop. While K-12 students are usually quite dutiful in filling out the feedback when ordered to do so, the adult learners tended to have a much lower response rate (around 60% compared to around 75% for K-12 students).

The age distribution of participants can be seen on Fig. 2. Majority of them participated in the workshop as part of their companies seminars or as part of continuing professional development. Some participants have been to the workshops as part of their companies' after-hours outings.

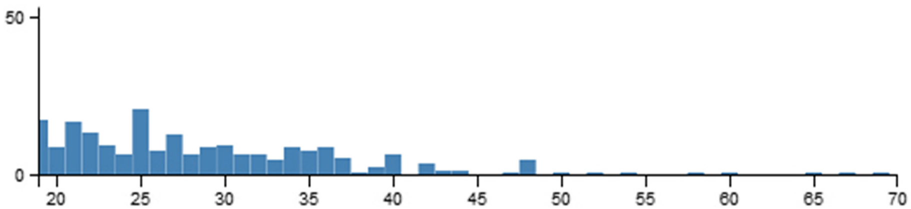


**Fig. 2.** Distribution of participants aged 19–70 years (n = 424)

36% of participants were female and 64% were male (exactly the same percentages were recorded with K-12 students). Majority of them, 88% had some previous connections with technology or engineering (91% for K-12 students) and 32% had previous programming experience (33% for K-12 students). Some stated using excel as a programming skill. Many mentioned learning programming languages like C, Java, Python or Pascal in university. Some had data base programming or command line experience. Web technologies were also mentioned. Few were actually professionals in information technology field. Comparing the variety of previous experience with K-12 students, there was much more versatility. 18% of adults (compared with 31% of students) stated that they had previous experience with robotics. Most common previous experience was during the studies years ago. Surprisingly, many stated that the experience during their studies with robotics did not come from universities but more from vocational schools. Some stated that they have seen or participated in robot competitions, used robots because of to work or have a hobby connected with robotics (for example, drones). Again, more versatility was observed with adults than with K-12 students whose main previous experience was after class school activities.

# 5 Analysis

## 5.1 Interests Before and After the Workshop

Participants were asked about their interest towards technology in general and then programming and robotics before and after the workshop. Technology in general had highest interest with 80% of participants stating high or very high interest beforehand. Robotics and programming had similar numbers for high interest (71% and 70%). Robots and programming show very similar percentage with all different interest levels as can be seen in Fig. 3.

The interest before workshop for adults is very similar to K-12 students. Adults have just a slightly higher interest which is expected as majority of them had already some connections with technology and were interested enough in those topics to consider training in the field.

When looking at how the workshop affected the interest, it can be seen that technology in general sees a highest rise with more than 70% stating that as a result of the workshop their interest towards technology rose. Robotics and programming see similar change with percentages with programming being just slightly lower. For both of them, 31% of participants stated that their interest remained the same and more than 50% recorded change.

Comparing the change of interest in adults with K-12 students shows that some differences can be observed. Adults are recording slightly higher rise in interest and they already had higher interest before. When with adults the programming and robotics showed very similar patterns, K-12 students had different patterns. For students, robotics showed a similar pattern as robotics for adults, with just slightly lower percentages. Programing, on the other hand, was more positively perceived by students than by adults as they were more likely to state high or very high rise in their interest. Therefore it could be said that students had more positive change in attitude towards programming as a result of the workshop.

When looking how the adults felt about the workshop, it can be concluded that majority of them found the workshop to be easy and yet the task to be very exciting. K-12 students, on the other hand, found workshop to be average on difficulty and found the workshop to be even more exciting than adults. The fact that students find the

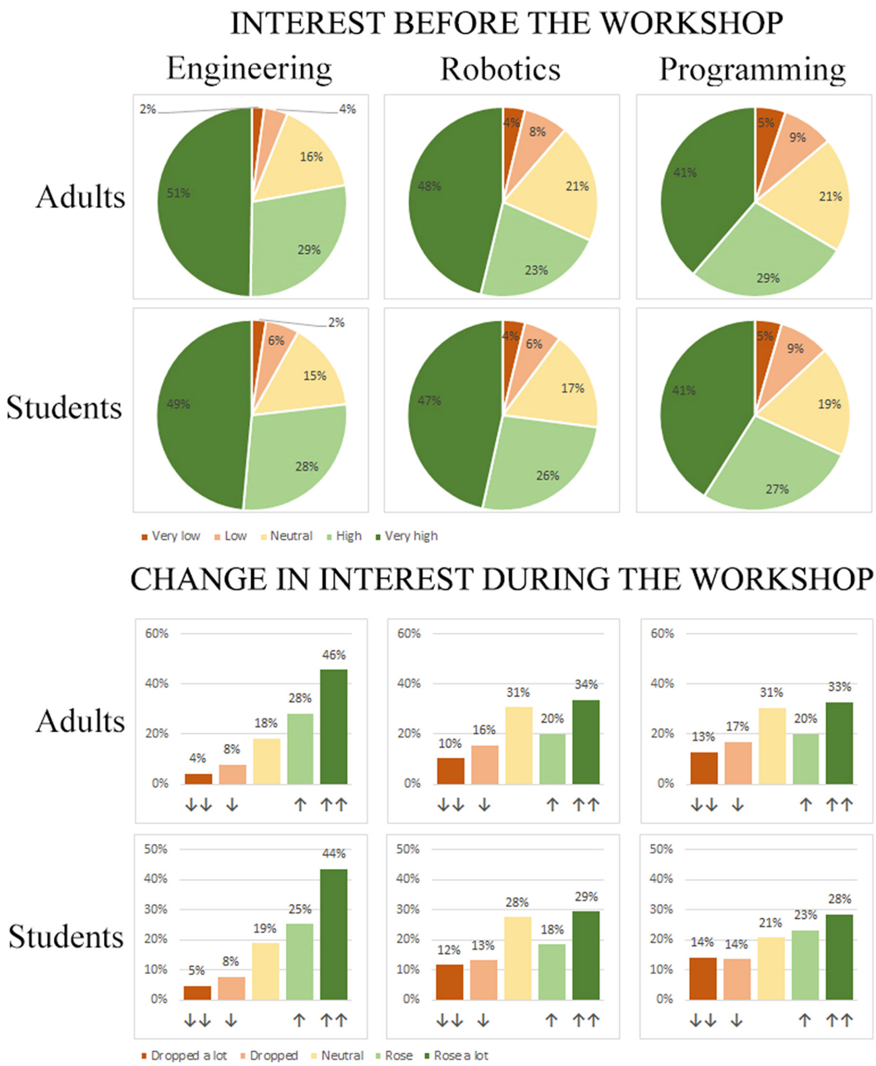


**Fig. 3.** Adult participants' interests before the workshop and how the workshop affected them compared with K-12 students

workshop to be harder than adults is expected as they have less experience from life. The fact that they are more excited is because many students are very young and haven't completely developed their interests. Younger the students, more exciting the found the workshop with another hike in interest for high school students.

When participants were asked which part of the workshop – building with Legos or programming they liked more, surprisingly, 40% of adults stated that they preferred the building and designing part. 38% preferred programming and the rest liked both aspects of the workshop equally. Comparing those percentages, students tended to like building with Legos more (47%) and 35% liked programming more.


**Fig. 4.** Adult participants' interests before the workshop and how the workshop affected them compared with high school students (16–18 years)

When comparing adults with oldest age group of students (high school, 16–18) as can be seen from Fig. 4, it can be seen that older students had much lower interest in the three considered field than adults did. They were remarkably less likely to state very high interest with most students stating high or average interest. Programming had the lowest interest. As the result of the workshop, older students also showed much lower rise in their interest with majority stating it remained the same.

Older students found the workshop to be slightly more difficult than adults and the task to be little less interesting. When adults hardly ever chose "Not interesting at all", some high school students picked that option.

### 5.2 Multiple Choice Questions

When looking at the multiple choice questions about the workshop, the most notable aspect is that adults are more likely to fill out the multiple choice questionnaires more carefully. With students, more than 10% of students were choosing "Do not know" option when filling the feedback which usually means that they did not pay much attention and just wanted to finish the form. With adults, the percentage is twice lower, around 5%.

When looking at the wrong answers, students recorded 39% of wrong answers of all the answers. Adults showed slightly better results with 31% of all wrong answers. Therefore adults, as expected, show better understanding of covered material.

As previously mentioned, the questions contained multiple correct answers reflecting different levels of understanding: being able to reflect the concepts in a context of task done in workshop, understanding the general idea of the programming block and showing high level of conceptual understanding behind the concept. Both students and adults were most likely to choose correct answer which shows general understanding of programming block (28% for adults and 21% for students). Adults also showed much high levels of understanding much more frequently with 22% of the answers compared to 17% for students. Surprisingly, the percentages reflecting the programming blocks in current task were almost the same (12% for adults and 13% for students).

The questions can be divided into two main subgroups – program flow questions and robot movements. Adults showed much better understanding of robot movements than students. They show 10–15% less wrong answers in movement questions and around the same percentage of more correct answers, reflecting a higher understanding of the movements. Most noticeable single question that stands out is robot's movement with two wheels that can have different speeds.

When looking at programming concepts, adults show a much better understanding of loop concept with 80% of answers showing the highest level of understanding. Also the question about a block playing sound (that has been always the easiest question) saw almost no wrong answers and in 92% of cases showed highest level of understanding. Surprisingly, switch concept sees remarkably lower results than with students.

Other differences between students and adults were not so significant.

When looking on general scores per person, average score for adults is up as would be expected. Surprisingly, adults do not have many perfect scores but they have higher percentage of very good scores. Adults also have a higher percentage of very low scores. Therefore, it could be said that adults do not stand out so much in getting all the answers correct in higher level but they, in general, have more correct answers and therefore higher scores. The percentage of high number of very low scores (associated with choosing "Do not know") also shows that some adults just want to skip the multiple choice questions and do not read them. Students, when they are skipping the questionnaire, still read the questions and answer at least the easiest questions (like question about sound block).

When comparing the results of oldest student age group (16–18) with adults, there are not many differences. Adults show better understanding of movement but lower percentage of correct answers with switch and interrupt block.

## 6 Discussion

The main research question for the study was to see if adults have similar perception that Legos are toys and are not open to use them for learning as some students or are they able to overlook the toy part of Legos and use them successfully in learning context. From the open ended questions it was not visible that adults had problem with using Legos for learning (no that kind of comments). Many of them have their own kids and thus have a connection with Legos from that. For others, Legos reminded them their own childhood and they were eager to re-connect with that aspect of themselves. In case of students, negative attitude has been recorded mostly with 13 to 15 years old who felt like Lego is for kids and, as young adults, it does not suit them. The only drawback from Legos for adults that was observed during the workshops was that adults had harder time dealing with small pieces (bigger hands than students) and they were slightly more reluctant to test unknown pieces by themselves and asked the assistant to check if the piece they took from the box is the one intended for this purpose.

It can be said that the fact that so many adults claimed preferring the building part of the workshop to programming is slightly unexpected as it was thought that building is harder for adults and programming is more exiting for them. It was also observed during the workshops that most of the adults were much faster builders than students. They built sensors by following instructions quickly but then spent a lot of time building the propeller that did not have any instructions. Therefore, it could be said that K-12 students were more opened to doing their own design and using their own imagination. Adults were also faster programmers and were able to spend more time testing different solutions and dared to go outside the instructor's given instructions and try novel/new approaches for the same problem (for example – replacing early in the workshop one wheel movement with two wheels to travel further).

When concentrating on the research question of learning effectiveness, the main observed advantage is that adults are able to gain more new knowledge during the workshop compared to K-12 students. They are also more likely to show a higher level of conceptual understanding about the programming blocks. That gain and higher level of understanding was expected as adults are usually more concentrated learners who have already more connections with technology thanks to work or other experiences.

It was also observed that adults are much better in understanding robot's movements. That was an unexpected result as it was actually assumed that programming flow concepts are easier to grasp by adults as they require a lot of high conceptual thinking and are not very easily describable to K-12 students in the context that they are familiar with. Ability to understand robot's movements may be connected to better understanding of physics, motion and cars or it can just be purely connected with better logical thinking.

Another quite an intriguing factor was that the percentage of female and male participants is the same for adults and students. With students it was recorded that teachers were forcing the gender roles on children and assumed that girls do not want to attend programming workshop. With adults, it could be assumed that those same gender roles have already been engraved into them and women are still less likely to participate in the workshops. The other factor may be that those companies attending the workshops have some interest towards technology or are already active in the field and therefore suffer from low numbers of females in the field.

The closer comparison between adults and high school students gave unexpected results. It was expected that adults show similar patterns as high school students. In reality, their results were very different. Main differences were the interests with high school students recording lower interests. It was mainly due very polarized answers by students – half of them were very excited and other half showed little interest. High school students have developed their interest – some are intrigued by technology, other not and therefore leading to polarized opinions. The same kind of polarization is expected also from adults. The situation with adults participating in the workshop (work related activities) slightly changes that balance towards more open minded attitude towards technology. The fact that adults have very positive change as a result of workshop opposite to students who already have their interest fixed is currently unexplained and requires more specific research. Overall, adults and high school students do not show similar results as were expected before the study. Adults are more like students in general with higher learning gain.

## 7 Conclusion

The aim of the study was to see if exactly the same workshop which has been used for K-12 students to give them first introduction with programming using Lego Mindstorms robots can also be used for adults coming from industry. So far very few authors have covered using Lego Mindstorms on grownups outside university/college students. It was found that the workshop is also very suitable for teaching adults how to program. The adults were faster builders and faster programmers. They showed, as expected, higher understanding of material covered during the workshop and were more likely to understand the concept behind the programming block than just reflect it back in current task as many K-12 students did.

Adults also showed a slightly higher interest before the workshop towards technology, programming and robotics and recorded that the workshop made their interest rise even further. In general, interests before the workshop were quite equal but how the workshop affected them, differs. For adults, the rise as a result of the workshop was noticeably higher, with both robotics and programming, which had similar percentages beforehand. For students, those two fields did not have a same pattern with programming, having more students stating a small rise than stating now change at all. Therefore, for K-12 students, the effect of first introduction to programming had slightly more positive effect.

Adults found the workshop to be easy and the task to be very exciting, recording more positive results than students. Adults also had a much higher variety of previous experiences with technology, robotics and programming than K-12 students.

Therefore, it can be concluded that the exact same workshop used for first introduction with programming using Lego Mindstorms and simple line following exercise can be used very effectively with adult learners.

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## References

1. Umbleja, K.: Can K-12 students learn how to program with just two hours? In: International Workshop on Learning Technology for Education in Cloud, pp. 250–264. Springer (2016)
2. Klassner, F., Anderson, S.D.: LEGO MindStorms: not just for K-12 anymore. IEEE Robot. Autom. Mag. **10**(2), 12–18 (2003)
3. Danahy, E., Wang, E., Brockman, J., Carberry, A., Shapiro, B., Rogers, C.B.: Lego-based robotics in higher education: 15 years of student creativity. Int. J. Adv. Rob. Syst. **11**(2), 27 (2014)
4. Álvarez, A., Larrañaga, M.: Experiences incorporating lego mindstorms robots in the basic programming syllabus: lessons learned. J. Intell. Rob. Syst. **81**(1), 117 (2016)
5. Korkmaz, Ö.: The effect of lego mindstorms Ev3 based design activities on students' attitudes towards learning computer programming, self-efficacy beliefs and levels of academic achievement. Balt. J. Mod. Comput. **4**(4), 994 (2016)
6. Lykke, M., Coto, M., Mora, S., Vandel, N., Jantzen, C.: Motivating programming students by problem based learning and LEGO robots. In: 2014 IEEE Global Engineering Education Conference (EDUCON), pp. 544–555. IEEE (2014)
7. Grandi, R., Falconi, R., Melchiorri, C.: Robotic competitions: teaching robotics and real-time programming with LEGO Mindstorms. IFAC Proc. Vol. **47**(3), 10598–10603 (2014)
8. Cuéllar, M., Pegalajar, M.: Design and implementation of intelligent systems with LEGO Mindstorms for undergraduate computer engineers. Comput. Appl. Eng. Educ. **22**(1), 153–166 (2014)
9. Kim, S., Oh, H., Choi, J., Tsourdos, A.: Using hands-on project with lego mindstorms in a graduate course. Int. J. Eng. Educ. **30**(2), 458–470 (2014)
10. Sauppé, A., Szafir, D., Huang, C.-M., Mutlu, B.: From 9 to 90: engaging learners of all ages. In: Proceedings of the 46th ACM Technical Symposium on Computer Science Education, pp. 575–580. ACM (2015)
11. Gómez, I.M., Rodríguez, R., Otero, J.J., Merino, M., Molina, A.J., Cabrera, R.: The role of small robots in designed play workshops in centers of adults with cerebral palsy. In: International Conference on Computers Helping People with Special Needs, pp. 515–522. Springer (2016)
12. Grey, F., Li, J., Shi, Q., Doney, E., Chen, W.H., Shen, J.: Lifelong learning lab: collaborative design of hands-on science for Chinese schools. In: Proceedings of the 14th International Conference on Interaction Design and Children, pp. 383–386. ACM (2015)

13. Leitão, P., Fraile, J.C., Moreno, V., Harrison, R., Altun, H., Colombo, A.W., Turiel, J.P., Curto, B.: Transnational lifelong education course in robotic systems. In: Industrial Electronics Society, IECON 2015–41st Annual Conference of the IEEE, pp. 004181–004186. IEEE (2015)
14. Umbleja, K.: The first year experience of using LEGO Mindstorms robots in the Tallinn University of Technology outreach program for secondary and primary school learners. In: New Technologies and Innovation for Global Business: ICEE 2015 International Conference of Engineering Education, Zagreb, Croatia, 20–24 July 2015, pp. 741–748 (2015)

# Work-in-Progress: Classroom-Based Experiential Education

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**Abstract.** Field-based Experiential Education has been used in higher education for decades in the form of internships, service-learning, etc. However not all students are in a position to take advantage of these opportunities. Classroom-based experiential learning activities offer students another way to deepen their learning. However, these activities need to be carefully designed, aligned to the course learning objectives and assessments, and include a meaningful reflective component. The purpose of this study is to identify examples of classroom-based experiential learning across disciplines. The first part of the study includes a search of the experiential education literature. Next steps will include semi-structured interviews and document analysis with professors who are willing to share their successful plans with colleagues. Ultimately the information gathered from the literature and interviews will be placed in a repository as a resource for faculty members.

**Keywords:** Experiential education · Assessment

## 1 Introduction

Experiential Education (EE) is not a new concept. The value of experience as an effective way of learning is expounded in oft- quoted sayings, such as: "Experience is the best teacher"; and "I hear, I know. I see, I remember. I do, I understand". As universities adapt and evolve, some are looking to EE to help students attain some of the knowledge, skills and attitudes needed for the 21st century.

In short, Experiential Education (EE) is "an approach to learning that bridges theory and practice by providing students with concrete applied practical experiences and then helping them to reflect on their experiences using the theoretical knowledge they have learned" [1].

Many disciplines either require or offer students opportunities for field-based Experiential Education (EE) through the use of co-op programs, internships, placements, practicums, service-learning, and so on. For example, at some universities, engineering students combine academic studies with work experience: academic terms alternate with work terms for a co-op program. It takes longer to complete a degree, but job prospects are enhanced. Undergraduate nursing students typically must complete a clinical placement. Bachelor of Education students are placed in cooperating schools to fulfil


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practicum requirements. In short, field-based EE has been successfully used by a wide variety of academic programs for many decades.

The University is committed to expanding and enhancing Experiential Education (EE) opportunities and many projects are underway for field-based experiential learning. However, for students who work part-time, who have family responsibilities, or have other constraints, these options are not always feasible. Experiential learning opportunities for students could be increased by including classroom-based EE activities. In spite of this, some Professors are hesitant to adopt classroom-based EE for a variety of reasons. They have asked for examples of classroom integrated EE activities, along with the associated assignments, and assessments. The literature is replete with general strategies but there are few detailed examples, especially with respect to reflective aspect of the experience and the assessment of experiential learning. In addition, the bulk of the literature deals with field-based EE and these cases do not always readily fit into a classroom-based learning experience. The goal of this study is to develop a repository of detailed relevant cases that could be used by instructors to develop appropriate classroom-based EE opportunities.

## 2 Conceptual Framework

Experiential learning can take many forms and vary on several dimensions; thus it is not surprising that there is no one definitive definition. However, the various approaches to experiential learning have common philosophical and theoretical foundations. In particular, John Dewey's body of work has been extremely influential. In addition, many researchers and practitioners have drawn on David Kolb's 1984 book entitled *Experiential Learning* [2]. Kolb himself drew on the work of John Dewey, Kurt Lewin and Jean Piaget.

### 2.1 Kolb's Experiential Learning Cycle

Kolb's experiential learning theory is best known through his four stage model of experiential learning. Many practitioners find Kolb's learning cycle provides a useful way to structure experiential learning opportunities. Kolb's experiential learning theory can be succinctly represented by a four stage model comprising: concrete experience, reflection, abstract conceptualization, and active experimentation.

The cycle begins with a concrete experience such as performing a lab experiment or solving a problem. In other words, the learner must do something, not just watch or read about it. The second stage, involves reflective observation. At this point the learner "steps back" and reviews what has been done or experienced. Many questions are asked at this stage, such as for example, why an experiment did not produced expected results. The third stage involves abstract conceptualization. It combines the experience, reflection and contextualizes theoretical concepts leading to new understandings. Finally, in the fourth stage the learner considers how they are going to take what they have learnt and put it into practice (Fig. 1).

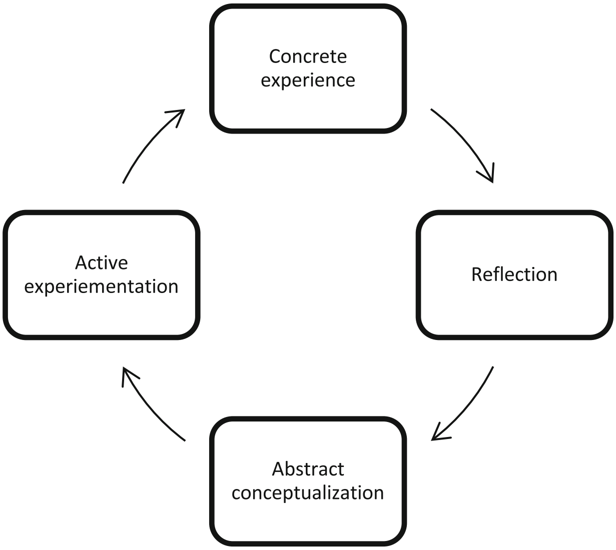


**Fig. 1.** Kolb's experiential learning cycle

### 2.2 Active Learning and Experiential Learning

One of the difficulties in reviewing the literature is that sometimes "active learning" and "experiential learning" are used as interchangeable terms. Sometimes the term active learning is used in the sense of a pedagogical approach. Other times active learning refers to a set of techniques to actively engage learners. Common active learning techniques and strategies include activities such as think-pair-share, 1-min paper, gallery walk, and so on. Occasionally "active learning" is used as an umbrella term that encompasses both the pedagogical approach and the classroom techniques.

For the purpose of this study, the classroom-based activity that was described in an article needed to include a reflective component in order to be considered experiential learning.

### 2.3 Reflection as an Integral Component of Experiential Learning

As the definition of experiential learning given in the introduction of this paper and Kolb's experiential learning cycle indicate: reflection is an integral component of experiential learning. The research literature affirms the importance of creating an effective climate and context for learner reflection though the clear alignment among intent, expectations, and authenticity [3].

### 2.4 Scaffolding the Development of Reflection

Reflection is critical component of professional practice, e.g. teaching, nursing, etc. and an important tool for developing higher order thinking skills. However not all students are equipped to engage in critical reflection [3]. Based on an extensive review of the literature, Coulson and Harvey [3] developed a framework for scaffolding reflection through four learning phases: learning to reflect (developing reflective skills), reflecting before an experience, reflecting during an experience, and reflection after the experience. The development of a learner's capacity to reflect will not always be strictly linear but the framework still aids in scaffolding.

# 3 Methodology

In order to develop a repository of examples, a search of the literature will be first conducted. Highest priority will be given to articles that include information regarding course goals or objectives, details of the experiential learning activity, details of the reflective activity and how it was assessed. The results will be used to begin building a repository with examples that could provide a starting point for professors who are interested in including Experiential Education (EE) into their courses.

In the second stage of the study, professors at the University who have successfully used classroom-based EE activities in their course(s) will be identified. They will be asked to share their materials. Through semi-structured interviews with these professors and document collection (course outlines, assignments, assessment tolls, samples of student work, etc.) data will be collected. These examples will thus be more detailed than those extracted from the literature.

Data from the literature search and interviews will be analyzed for similarities and differences (e.g. class size, year of study, discipline, and so on), which will allow a categorization of the examples.

## 3.1 Search of the Literature

A search of the literature was performed using ERIC (Education Resources Information Center). ERIC is an authoritative database of indexed and full-text education literature and is the most important index in the field of education. Coverage is from 1966 to the present. The search was not limited by date. It was limited to peer-reviewed and scholarly journals. Due to resource limitations, the search was limited to English language publications. For the Education level, the search was limited to Higher education, and Post-secondary education.

The following keywords were used during this search; experiential learning, classroom-based OR in-class, and outcomes OR objectives.

# 4 Findings

Using the parameters listed in the previous section, 36 results were initially identified. The abstracts of each result were analyzed to confirm that the article did indeed meet the criteria, i.e. classroom-based not field based Experiential Education, inclusion of a reflective component. This led to the exclusion of 18 articles mainly because they were field-based Experiential Education, e.g. service learning. Articles that described online activities were included in the study if their classroom was considered to be a virtual classroom and did not have the constraints of field-based EE activities.

A reading of the articles led to a further six being excluded: three were field-based EE, one was an active learning class without a reflective component, one was an earlier version of an article and one was a discussion of the pedagogical benefits and challenges of using peer educators.

A preliminary analysis suggests that innovative approaches to integrating classroom-based Experiential Education (EE) opportunities have been used in a variety of class sizes and disciplines. The articles chosen for this study contain sufficient explanation of activities and how-to-implement them. Several have also included de-briefing and reflective questions that could be adapted for different scenarios. None of them made use of Coulson and Harvey's framework [3]. Finally, in class simulations and the use of the Internet are being used to overcome some of the constraints of field-based experiential learning.

## 5 Discussion

Field-based Experiential Education (EE) continues to hold a place in higher education. There is a growing body of literature on field-based EE. For example, service-learning is the most widely analyzed form of experiential learning in higher education [2]. However, not all students are able to or want to, participate in field-based EE. Classroom-based EE is not only an alternative to, but can also complement field-based EE. The brief search of the literature indicates that some faculty members have found innovative ways to bring the benefits of experiential learning into their classroom. In addition they are willing to share their materials with colleagues.

Several of the articles described simulations. These preliminary results suggest that a more comprehensive search that includes other subject databases, such as the Nursing and Allied Health Database, would be worthwhile.

In some of the studies, the link between the experiential learning activity and the course learning objectives/outcomes was not always clear. In the second part of this study, i.e. the semi-structured interviews with faculty members who have successfully implemented in-class experiential learning activities, there will be the opportunity to pursue this question. Thus, the two methods of obtaining data seem to be complimentary.

## References

1. York University: White Paper Companion, April, 2010. http://vpap.info.yorku.ca/files/2012/09/White_Paper_Companion_April_15.pdf. Accessed 6 Apr 2017
2. Moore, D.T.: Forms and issues in experiential learning. New Dir. Teach. Learn. **2010**(124), 3–13 (2010)
3. Coulson, D., Harvey, M.: Scaffolding student reflection for experience-based learning: a framework. Teach. High. Educ. **18**(4), 401–413 (2012)

# Computer Aided Language Learning (CALL)

# Engineering Pedagogy Terminology

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**Abstract.** English has become the main working language of IGIP, which contributed greatly to the dissemination of Engineering Pedagogy ideas all over the world. But at the same time, it has caused some problems with proper understanding and usage of Engineering Pedagogy terminology. In order to overcome these difficulties, the authors suggest compiling “IGIP Multilingual Glossary”. For that purpose we propose to use the approach already applied in English-Russian and Russian-English Learners’ Concise Terminology Dictionary “Engineering Pedagogy” that has been worked out in Moscow Automobile and Road Construction State Technical University (MADI). It is intended for university educators who teach technical disciplines in English, as well as for post graduate students who are trained for pedagogical activities. The paper describes the lexicographic concept, similarities and differences of the structure and contents of the two dictionaries.

**Keywords:** Engineering pedagogy · Terms · Glossary
Concise terminology dictionary

## 1 Context

The development of Engineering Pedagogy, and especially the Klagenfurt School of Engineering Pedagogy, is closely connected with IGIP – “die Internationale Gesellschaft für Ingenieurpädagogik”. IGIP was founded during the First International Symposium on Engineering Pedagogy, which took place in Klagenfurt (Austria) in 1972 [1]. At the early symposiums, 90% of the speakers were from German-speaking countries. They were able to meet and exchange their views without any language barriers. The main, most cited and referenced work on Engineering Pedagogy “Ingenieurpädagogik” by A. Melezinek was also written in German. Only later, in the 1990s, it was translated into Hungarian, Czech, Slovenian, Russian, Ukrainian, Bulgarian, and Polish. So at that time, at the beginning of IGIP, it was only natural that German used to be the working language of the Society, Symposiums, and Symposium Proceedings.

In the 1990s, as more and more educators from various countries were joining IGIP, the symposium speakers made presentations and published papers in Symposium Proceedings either in German or English. “Report” - the official journal of IGIP - was also published in these two languages. And since the 2006 Symposium in Tallinn


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(Estonia), the Association has switched to English, and English has become the main working language of IGIP and its conferences [1].

English as a means of international communication has contributed greatly to better understanding and exchange of Engineering Pedagogy ideas, facilitating their dissemination all over the world. However, at the same time it has caused certain problems with Engineering Pedagogy terminology. The first problem is improper usage of terms by non-native speakers. The second one is more subtle and is connected with the semantics of the terms. Quite often representatives of different countries may use the same term but bear in mind different interpretations of its meaning. Translating a term from our native language into English and being focused on its form, we tend to forget that in our native language a term reflects a national pedagogical theory or a system of education. Two clear examples come from the English version of IGIP name and the term "credit". At first, "die Internationale Gesellschaft für Ingenieurpädagogik" was translated as "International Society for Engineering Education" and later as "International Society for Engineering Pedagogy". As for the word "credit", when conference participants hear it, they may interpret it in the range from 36 h to 20 h depending on the country they represent.

As the proper usage of Engineering Pedagogy terms causes difficulties for some IGIP members who are non-native English speakers, it sometimes leads to misunderstanding of presentations and papers. Engineering Pedagogy terminology, like any other specific terminology, as well as the ability to use it properly in new situations of professional communication, is considered to be part of linguistic competence, which is a fundamental component of foreign language communicative competence of university teachers. So the ability to use Engineering Pedagogy terminology properly is of vital importance to IGIP members.

Engineering Pedagogy terminology is also necessary for university educators who teach international students in English at home or abroad. This terminology will be useful for technical universities post graduate students who are trained for pedagogical activities besides research. The requirement to know specific terminology is defined by the Russian Federal State Educational Standards for Master's and PhD students [2]. The Standards emphasize the necessity of terminology terms knowledge but do not give any information concerning the number of terms to be learnt.

## 2 Goal

The final goal of the suggested project is to compile an Engineering Pedagogy glossary. Glossary is a list of terms in a special subject, field, or area of usage, with corresponding definitions [3]. The proposed title is "IGIP Multilingual Glossary". The glossary should consist of the English core - basic Engineering Pedagogy terms with definitions in English, to be followed by translations into the target languages of IGIP members or participants. It means that Russian, German, Hungarian, Czech and other languages will be added to this basic list later. If there is a difference in the interpretation of a term meaning, definitions of the terms may be added in the target languages.

Compiling any glossary gives rise to a variety of problems. The most evident one is the selection of terms. The selection of lexical units has always been one of the key tasks of the teaching methods of foreign languages. The process of selecting basic or specific vocabulary is based on, for example, the frequency principle of its usage in a speech activity. But as a rule, teachers select specific terms and compile the word lists from the texts at hand at the moment and following their own experience and intuition. As a result, terminology lists do not always reflect the notional structure of a field of knowledge, the logic, the main sections and interconnections in a field of knowledge.

Still another problem is the number of terms necessary to learn, their arrangement in the glossary, and the techniques of learning. When determining the number of terms, it is necessary to bear in mind that the terms selected should be the nucleus of the terminological system of a particular field of knowledge and have the potential for further learners' vocabulary increase.

In order to achieve the goal of compiling "IGIP Multilingual Glossary" and to solve the above mentioned problems, it is possible to use English-Russian and Russian-English Learners' Concise Terminology Dictionary "Engineering Pedagogy" ("EP Dictionary") as the basis. "EP Dictionary" is one of the bilingual dictionaries in the series "Learners' Concise Terminology Dictionaries" published in Moscow Automobile and Road Construction State Technical University (MADI) in the framework of the University Strategic Development Plan (2012–2016).

Within the series, a number of two/three language concise dictionaries have already been published, and additional issues are being prepared. They are aimed at post graduate students at the second and the third level of higher education and students of additional professional program "Translator in the Sphere of Professional Communication". They can be used for acquisition of the main terminology during class work and/or self-study. They are also useful for teachers of English when compiling programs, text books, manuals, etc. The series contains English-Russian and Russian-English Learners' Concise Terminology Dictionaries "Transportation Tunnels", "Automobile Roads", "Automobile Service". There are also three language dictionaries, for example, Russian-Chinese-English Learners' Concise Dictionary "Automobile Bridges".

"EP Dictionary" is intended for post graduates in higher education pedagogy and for further retraining of technical teachers under the additional program "Methods of Teaching Disciplines in English" being launched at MADI.

In conducting the research in order to compile the above mentioned series of learners' concise dictionaries we set the following objectives:

- to determine basic theoretical statements;
- to determine the method of terms selection and the number of terms;
- to formulate lexicographic concept of learners' concise terminology dictionaries;
- to write a prospectus of a typical dictionary;
- to compile the dictionary "Engineering Pedagogy".

It is also necessary to show similarities and differences of the main statements of the lexicographic concept for "IGIP Multilingual Glossary" and "EP Dictionary".

## 3 Approach

The first task is to determine the basic theoretic statements. For that purpose, we analyzed classical and modern lexicographic literature and works on the methods of teaching foreign languages. The basic theoretical statements are defined as follows.

The theory and practice of compiling dictionaries are the domain of lexicography, which is part of linguistics. The compiling of learners' concise terminology dictionary is based on specific, terminological and didactic lexicography.

Specific lexicography that describes languages for specific purposes and their terminology deals with creating dictionaries for particular fields of knowledge. The significance of specific terminology dictionaries is generally recognized, and there are a lot of modern bilingual terminology dictionaries for various technical subjects. However, because traditionally they include up to several thousands of terms, it is impossible to use them effectively to learn relevant but limited number of terms.

Terminological lexicography describes a specific field of knowledge. It is very close to specific lexicography, and some specialists do not distinguish them [4]. The peculiar feature of terminology dictionaries is that they describe the terms systematically and they are profession oriented.

Learners' dictionaries refer to didactic lexicography. Their aim is to describe a lexical unit either in a theoretical or practical way for the purpose of teaching and learning a foreign language [5]. The description may be given as a list of words, a vocabulary, a glossary, or a concise dictionary. Didactic lexicography is not academic, it is teaching and learning oriented.

A learners' concise dictionary refers to terminology lexicography and didactic lexicography. A term is an "atom" of any terminology dictionary. In terminological lexicography, the notion of a term may be defined from different points of view. We adopt one of the most general definitions of a term, according to which a term refers to a word or a phrase denoting the concept of specific fields of knowledge or activity [6].

A term can be a component of the basic stock of a language but it enters it through a certain terminology system. A term is characterized by belonging to a system, it is monosemic, has a definition, shows absence of expressiveness and stylistic neutrality. It is common knowledge that monosemy is necessary for effective professional communication due to clear definitions based on the achievements of a certain field of knowledge or science [6]. A term is considered to be the most informative unit of a language. It reflects scientific and professional knowledge of the objects and phenomena, and its definition determines its most relevant characteristics. Thus it is better to have definitions of terms in a learners' concise terminology dictionary.

As an object of didactic lexicography, a learners' concise dictionary can belong to any genre, can contain any number of words as a tool of learning a foreign language. The purpose of the dictionary determines its peculiarities and characteristics. Learners' concise terminology dictionaries play an important role in profession oriented foreign language teaching. They contain a limited number of words, and due to this fact they are lexical minimums.

In the methods of foreign language teaching, lexical minimums are considered to be a collection of language units compulsory in reaching the level of communicative competence required by a program corresponding to a certain level of education [5]. Besides, lexical minimums contain lexical units that should be acquired within a certain period of time. So any learners' concise terminology dictionary is a collection of foreign language terms in a certain field of knowledge necessary to acquire by learners within a specific period of time at a certain level of education [7]. As for "IGIP Multilingual Glossary", it can be defined as a collection of the English terms of Engineering Pedagogy to facilitate professional communication between IGIP members.

Learners' concise terminology dictionaries are characterized by selectiveness, i.e. the terms are selected using a variety of approaches. Nowadays in lexicography and linguistic didactics there are several approaches to terms selection: the empirical, statistical, sociolinguistic, linguistic and subject-based methods. In didactic lexicography, there is no agreement on the best approach to selection of terms. The empirical approach is predominantly based predominantly on the work experience of a particular teacher. Statistical approach deals with frequency of terms occurrence in scientific and technical texts. Linguistic approach takes into account the semantic value of terms, compatibility of lexical units, their derivational value, etc. Sociolinguistic approach factors in the learner-user needs in their professional activity. Unfortunately, all the above methods have proved to be insufficient for teaching for specific purposes.

The most promising is the didactic approach, which follows the purpose of the dictionary, specific teaching levels objectives, and the terms of its implementation. The purpose of the learners' concise terminology dictionary is to help learners to acquire the basic specific terms in a certain field of knowledge, which can be achieved most effectively applying the subject-based principle to selection of terms [7]. According to this principle, the selection is based on the logic and semantic value of terms for a particular field of knowledge.

Due to the work of experts, the subject-based principle gives the opportunity to select the most relevant professional terms that are the core of a certain terminology system, and to arrange them by sections reflecting the logic of a science, as well as its structure and classification of notions. The subject-based principle can be considered to be the next step in developing the principle of situational and thematic presentation of the teaching material.

As for the number of terms, the minimum number of specific technical terms required for the Bachelor level of technical education is about 160 lexical units [8]. Therefore, we have concluded that the dictionary volume of 400 Engineering Pedagogy terms will adequately meet the needs of the post graduate students. The usage of the series of learners' dictionaries in the teaching process has proved this quantity of terms sufficient. The volume of "IGIP Multilingual Glossary" may be much larger, as it should contain the terms relevant to various IGIP Working Groups, which may coincide with regular topics of annual conferences, and, therefore, the final number should be defined by cooperative work of their representatives.

## 4 Actual and Anticipated Outcomes

Having determined the initial theoretical statements, quantitative characteristics of the terms and the method of their selection, we were able to work out the lexicographic concept of a typical learners' terminology dictionary. It defines the dictionary's purpose, target audience, macrostructure, and microstructure.

As for the purpose and the target audience, "EP Dictionary" helps Russian university professors to learn the pedagogical terms necessary for teaching international students effectively. At the same time, it is useful for students of the second and third level of education, specializing in pedagogics.

The purpose of "IGIP Multilingual Glossary" is to help international IGIP members and non-members interested in promoting engineering education to use Engineering Pedagogy terms properly to exchange opinions, make presentations, write papers for international conferences, work together in international teams, and communicate during academic mobility programs.

As for the macrostructure, "EP Dictionary" innovative structure consists of a preface, a guide to use the dictionary, the main English-Russian subject section, English-Russian alphabetic section, Russian-English alphabetic section, conclusion, references, and appendices.

"IGIP Multilingual Glossary" is to have a preface, a guide to use the dictionary, the main English-Russian subject section, and references. Taking into consideration multilingual character of the dictionary, it is next to impossible to prepare alphabetic sections, though they proved to be very useful while making presentations, writing papers or reading scientific articles.

Both dictionaries have prefaces, which state the purpose of the dictionary, its target audience and the basic statements of the lexicographic concept applied, which reflect similarities and differences in the approaches.

The guides should give clear instructions on the dictionary usage. The guide of "EP Dictionary" explains how to use a paper version and the system of indexing terms into three sections, their coordination with appendices, and other details pertinent to a more complicated macrostructure of the dictionary. Electronic version of "IGIP Multilingual Glossary" on IGIP site will be accessible to all the members to be used at their convenience. Therefore, the Guide to this dictionary will be significantly different.

The subject section is the main section, which comprises all the terms of the dictionary. In "EP Dictionary" there are about 400 words and word combinations. In "IGIP Multilingual Glossary", the number of terms may be much larger. But in both dictionaries, the terms are to be arranged in sections and subsections in a logical order. In "EP Dictionary", the same terms are presented in the three sections of the Dictionary. They are numbered, and the system of cross-references provides the quickest way to locating the term in any section, or its illustrative representation in the appendices.

The conclusion in "EP Dictionary" provides recommendations on the dictionary self-study work, the titles of periodicals, etc. In references one can find the names of the works used when compiling the dictionaries. These are lexicographic and didactic works, textbooks in English, bilingual dictionaries, and terminology thesauruses.

Appendices in Engineering Pedagogy Dictionary contain additional educational help in working with the dictionary.

On the microstructure level an entry is its main structural unit. The entries of the subject sections of both dictionaries can be the same. An entry contains a term in English (presented by one word or word combination) that is followed by its generally acceptable definition. On the one hand, it reflects the usage of a term in scientific literature, on the other hand, the entry format allows learners and users to understand and memorize it as a unity. After each term comes its pronunciation. Transcription symbols indicate a correct sound of a particular term, which is vital for oral communication.

In both dictionaries, there are three methods of explaining the meaning of each term - its equivalent in the target language, its definition and its illustration. In "EP Dictionary" there is a translation into Russian. In "IGIP Multilingual Glossary" there will be translations into various target languages spoken by IGIP members. As soon as a new country joins IGIP, a new target language can be added.

It is important to underline the fact that the major part of the terms is supplied by their definitions in addition to their equivalents, thus illustrating a particular meaning of the term within a specific context. Importantly, "IGIP Multilingual Glossary" should have definitions in the source language, and if they vary from the target languages, definitions in these languages can also be provided. Some illustrations in the form of pictures, graphs, and charts can be added to illustrate the meaning of the term.

Necessary lexical comments are provided to complete the meaning of lexical units.

"EP Dictionary" has alphabetic sections, which have identical structure but in a reduced form. They contain terms in the source or target language, its equivalent and its number, which corresponds to the subject section.

The lexicographic concept is the basis for the prospectus of a bilingual and a multilingual dictionary.

## 5 Conclusions

Since the 2006 Symposium in Tallinn (Estonia) English has become the working language of IGIP and its conferences. English as a means of international communication contributed greatly to dissemination of Engineering Pedagogy ideas all over the world. But at the same time, it causes some problems with Engineering Pedagogy terminology for some IGIP members who are not English native speakers.

In order to overcome these difficulties, it is necessary to start a project, which goal is to compile an Engineering Pedagogy glossary. "IGIP Multilingual Glossary" should contain basic Engineering Pedagogy terms and their definitions in English as its core, equivalents in the languages of IGIP countries where definitions will include the differences in meaning and education systems.

The lexicographic concept of "IGIP Multilanguage Glossary" has been developed and implemented in the English-Russian and Russian-English Learners' Concise Dictionary "Engineering Pedagogy". The concept successfully solves the problems of terms selection, the number of terms, macro- and microstructure of the glossary.

The English-Russian and Russian-English Learners' Concise Dictionary "Engineering Pedagogy" has an innovative structure containing the following sections: a preface, a guide to use the dictionary, the main English-Russian subject section, English-Russian alphabetic (cross) reference, Russian-English alphabetic (cross) reference, conclusion, references, appendices. The dictionary contains the terms that can be translated into the languages of the countries participating in IGIP activities. "IGIP Multi-language Glossary" will contribute to better understanding and further development of Engineering Pedagogy.

## References

1. Prikhodko, V.M., Polyakova, T.Y.: IGIP: International Society for Engineering Education: Past, Present, Future. Tekhpoligraftsentr Publishing, Moscow, p. 143 (2015). Приходько ВМ, Полякова ТЮ, (2015) IGIP. Международное общество по инженерной педагогике: прошлое, настоящее и будущее: монография. Техполиграфцентр, Москва, с. 143
2. FSES HE training program in the field of construction, p. 15 (2014). 08.04.01, Master's degree. ФГОС ВО по направлению подготовки (2014) 08.04.01 Строительство (Уровень магистратуры), с. 15
3. Dictionary.com: Meanings and Definitions of Words at Dictionary.com http://www.dictionary.com/browse/glossary
4. Sager, J.C.: Terminology and the Technical Dictionary. Niemeyer, Tübingen, p. 326 (1984). Hartmann, R.R.K. (ed.)
5. Azimov, E.G., Schukin, A.N.: Glossary of Methodological Terms, p. 472. Zlatoust Publishing, St. Petersburg (1999). Азимов ЭГ, Щукин АН, (1999) Словарь методических терминов. Златоуст, С.-Петербург, с. 472
6. Yartseva, V.N. (ed.): Linguistic Encyclopedic Dictionary. Soviet Encyclopedia, Moscow, p. 684 (1990). Ярцева ВН, (Гл. ред.), (1990) Лингвистический энциклопедический словарь. Советская энциклопедия, Москва, с. 684
7. Polyakova, T.Y.: Terminology as a basis for the development of foreign language communicative competence of engineers. Bulletin of the Federal State Educational Institution of Higher Professional Education Moscow State Agroengineering University named after V.P. Goryachkin, pp. 31–34 (2012). Полякова ТЮ, (2012) Терминология как основа формирования профессиональной иноязычной коммуникативной компетенции инженера. Вестник ФГОУ ВПО МГАУ им. В.П.Горячкина, стр. 31–34
8. Pozdnyakova, S.Y.: Cognitive approach to selecting and arranging of concise terminology dictionary of technical military aircraft terminology (German language, non-language HEI). Irkutsk, p. 217 (2005). Позднякова СЮ, (2005) Когнитивный подход к отбору и организации учебного словаря-минимума узкоспециальных военно-авиационных терминов (немецкий язык, неязыковой вуз). Иркутск, с. 217

# On-line Testing of Engineering Students as a Form of Assessment when Studying English in Distant Form

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**Abstract.** One of the most significant aspects of training foreign language is the objective assessment of the knowledge. Assessment in the form of on-line testing leads to reducing time spent on it, quick feedback and analysis of results, individualization of the assessment procedure, and developing self-discipline. The purpose of the study is to analyze the assessment procedure of future engineers who study English in the framework of distant program "Translator in the sphere of professional communication". As personal interaction between a student and a teacher is limited, the online assessment in the form of testing that is able to measure the knowledge of students effectively stands forward. Incoming, intermediate and final tests are analyzed; results of students and their feedback are examined. A multiple-choice testing task is selected for thorough examination as the most commonly used.

**Keywords:** Distant learning · Online testing · Multiple-choice

## 1 Peculiarities of Assessment when Training Foreign Language

Introduction of distant elements is of great importance in contemporary education. Distant education proved to be successful because of the following: strong motivation of students, online resources to improve the language, comfortable atmosphere, and a smaller cost of the course. An objective assessment of the knowledge is an important aspect of this type of study.

Accurate assessment must perform the following functions:

(1) monitoring (to monitor the skills and competences),
(2) training,
(3) diagnostic (to evaluate the quality of teaching, define the mistakes and gaps in the knowledge which can help organize further studying process),
(4) correcting,
(5) educating (to develop individual responsibility for quality of knowledge and ability to overcome difficulties on one's own),
(6) estimating (to present results of assessment),
(7) directing (to direct further educational process taking into account student's abilities),
(8) developing (to stimulate cognitive activity of students) [2].


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The aim of the assessment is to evaluate a maximum number of students in a minimum period. The volume of material under evaluation should be limited but representative. The assessment is supposed to be regular, targeted, objective, systematic, effective, planning, economic, and clear. Besides, it must correspond to the objectives of the course.

Supporters of traditional approaches are sure that knowledge of students can be checked only if a lecturer is face to face with students, because it is possible to ask additional questions to find out whether a student knows the subject or not. The assumption seems reasonable but economy of time and efforts of teachers, students as well, should be taken into account.

A test is considered to be a system of tasks which have increasing difficulty, specific form and allow to measure the level of knowledge effectively. That means the knowledge is to be assessed with the help of minimum number of tasks that can evaluate the knowledge quickly and with minimum efforts [2, 3].

## 2 Peculiarities of On-line Testing

Assessment in the form of on-line testing leads to reducing time spent on the performing, quick feedback and analysis of results, individualization of the assessment process, and developing of self-discipline. As personal interaction between a student and teacher is limited, the on-line assessment in the form of testing that is able to measure the knowledge of students effectively stands forward. It should perform not only the function of control but have educating potential as well. In other words, the results are interpreted to identify the issues that have not been mastered and are supposed to be trained again [4]. The tests are demanded to be valid, reliable, scorable, economical, and easy to administrate [3].

On-line testing meets the following organizational requirements:

(1) A student must know beforehand a number of tasks and a recommended time to fulfil them.
(2) A student must have a chance to perform a demo version of the test to be aware of the interface.
(3) When testing, only one task must be displayed on the screen for a student not to be confused.
(4) The interface itself must be simple and clear.
(5) The input method should be simple and comfortable.
(6) A student must have an opportunity to confirm the input, correct answers, miss the task and then return to it, be aware of the result.

The content of the test is worked out according to the following principles:

(1) The content of the test must be consistent with the objectives.
(2) The most important elements of the course must be included in the test.
(3) The content and the form of the test are interconnected.
(4) The information of the course should be represented accurately in the test.

(5) A number of tasks usually is not more than 30 and it depends on the content of the material assessed and the type of the test.
(6) The content must be systematic and balanced.
(7) The variants of the text must be of equal complexity.
(8) The tasks in the test must have increasing difficulty [1–3].

The testing tasks must be logical, short, right, and accurate, with a certain place for an answer and clear instructions. Besides, the rules of estimation are to be transparent.

## 3 Multiple-Choice Testing Task when Testing On-line

The data are taken analysing the program "Translator in the sphere of professional communication" realized in Kazan Federal University and Kazan National Research Technological University. The methods of investigation such as observation, analysis of previous experience, and survey of students are used.

The types of courses studied were taken into account as a number of tests used depends of whether the course contains theoretical aspects or is practically oriented. Practical courses (Practice of Speech, Professional Translation) demand creative approach and tests are limited in use. Use of multiple choice to check the skills of translation is possible only when finding synonyms, antonyms, and adequate translation of the word or set expression in the context as translation is a creative process. The tests here are heterogeneous that means they demand knowledge of the engineering subjects. The second group of subjects (Theory of Translation, Stylistics, Theory of Grammar, and Business Communication) has mixed form of assessment: individual tasks and on-line testing are used; tests are used to check knowledge of theoretical aspects.

Three types of tests are defined based on the period of use in the framework of the program "Translator in the sphere of professional communication":

(1) Incoming tests that are used to measure the incoming level of the student. This type of testing helps organize a further study effectively.
(2) Intermediate (midterm) tests that are taken after passing certain modules (3–4 modules are typical for each course).
(3) Final test that can be a part of final after finishing the course.

The task is formulated in two ways:

1. To answer the question. For example,

   What does Semantics study?

a. The origin of the word
b. The meaning of the word
c. The phonetic structure of the word

2. To complete the sentence. The gap in the sentence can be in the beginning, in the middle or in the end. The latter is considered the easiest by the students, which may be explained by the position of the communicative centre in the sentence. For example:

The methods of sociolinguistic can be divided into two groups:

a. finding and experiment
b. analysing and experiment
c. finding of material and analysing
d. finding of material and collecting

Traditionally the following types of testing tasks are used when assessing the knowledge of students: matching, true/false, multiple choice, rearrangement, completion, substitution, transformation, paraphrasing, and cloze-procedure. When testing on-line future engineers in the framework of the program "Translator in the sphere of professional communication" the following types of testing tasks are recommended: multiple choice, true/false, matching, cloze-task. The multiple-choice type with a number of options ranging from 3 to 5 is selected for thorough examination in the research as the most commonly used.

Analyzing the subjects that focus on theoretical aspects of the language, the information requested from the students can be summarized as follows:

(1) Numbers or percentages. According to feedback of the students, this type is the most difficult. For example,

Tatar was converted to Cyrillic alphabet in _____.

a. 1992
b. 1958
c. 2003
d. 1938

A municipality can be stated bilingual if ______ of population speak the second language.

a. 1%
b. 10%
c. 50%

(2) The definition of the term. A term can be presented in the prompt and three/four options as the definition are offered. For example,

The hypercorrection is _______.

a. a kind of slang
b. a perfect language spoken by high class
c. a language spoken by the uneducated
d. mistakes in speech made imitating good English

(3) Cause-effect relations. This type of question is aimed at training cognitive skills as well. For example,

The coastal areas in the US in the $19^{th}$ century kept non-rhotic speech because ______.

a. they liked it more
b. the elite classes were in touch with English prestige patterns

c. there were more people from high class living in the districts
d. the population was more acceptable to non-rhotic speech

(4) The example of the phenomenon. Here two types of the task can be defined. According to the first one, the sample of a certain linguistic phenomenon is given and a student must define it. The second one present the task where, on the contrary, the linguistic phenomenon is named and the example should be chosen. For example,

Analyze and define what stylistic device the author resorts to:
The green *tumor of hate burst* inside her.

a. simile
b. metaphor
c. metonymy

Which of the following devices is a *simile*?

c. Gentleman of a long robe
b. He is as brave as his father is
c. Treacherous as a snake

(5) A combination of options. The students consider this type confusing, as it requires attention and concentration from them. It is characterized by the fact that the options contain the facts in different combinations. For example,

The language can preserve information in two spheres:

a. the language itself and written reports
b. oral reports and written reports
c. the language itself and in the speech

Assessment of knowledge in online testing form when studying practical courses include testing tasks aimed at finding synonyms or antonyms, defining the meaning of the word in the text. Here the task requires choosing the right translation of the word taking into account the context. The most widespread words are those that are poly semantic. For example,

Choose the best correspondence to the word *to strike* in the following sentence:
The striking unions have won concessions despite bitter opposition of the employers.

a. бастующий
b. поражающий
c. бьющий

Choose the best correspondence to the word *погибла* in the following sentence: Она погибла в авиакатастрофе.

a. died
b. was killed
c. was shot

The skill of translation of phraseological units and set expressions can be checked with the help of on-line testing as well. The translation itself is a creative process, as it is mentioned above, that is why the use of tests when checking it is restricted. For example,

Choose the best correspondence to the sentence:

Сам живи и другим не мешай

a. Rome was not built in a day
b. New lords – new laws
c. Live and let live
d. Seek and you shall find

The tests were approbated and the following inaccuracies of the first testing tasks were pointed out by the students and eliminated: a number of options should not be more than four and shouldn't be guessed due to grammatical peculations, the test should have only one type of questions, for example, multiple choice.

## 4 Conclusions

Systematic use of testing as a specific form of measuring the level of knowledge is an adequate method of assessment that can raise self-discipline of students. Besides, it leads to reducing time for assessment and getting rapid feedback. As students do not have enough opportunity to communicate with a teacher directly, assessment must perform functions of teaching as well as control. Multiple choice as the most widespread type of question can be used in combination with tasks and other types of tests. A degree of testing use depends on the type of the course. If we do with theoretical subjects on-line testing can be actively used checking theoretical aspect of the knowledge. Multiple-choice questions can require the following information: numbers, the meaning of the term, cause-effect relations, the example, the position of the phenomena, and the right combination of facts.

## References

1. Semushina, E., Ziyatdinova, Y.: Final project of graduate engineers as realization of principle of combinatory when teaching English in distant form. In: Proceedings of 2015 International Conference of Interactive Collaborative learning, pp. 296–298 (2015)
2. Avanesov, V.: Teoria I metodika pedagogicheskih izmerenii (2005). 98 p
3. Lado, R.: Language Testing: the Construction and Use of Foreign Language Tests. Longman, London (1961). 398 p
4. Semushina, E., Galeeva, M.: Distant form of mastering translator's competence as a part of engineering education in Kazan Federal University. In: 16th International Conference on Interactive Collaborative Learning, pp. 519–521 (2013)

# Engineering Students' Needs in Foreign Language Studying in Russia

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**Abstract.** The foreign language training system in engineering education is based on the research of engineers' needs in foreign language implementation in their professional activities. Further development of the system requires also determination of engineering students' needs in foreign language studying. The research is conducted as a joint Russian-Czech project with two Universities involved (MADI and the University Hradec Kralove). The purpose of the project is to identify the needs of learners of engineering universities in studying foreign languages depending on the level of higher education, their specialty, etc. In order to achieve the research objectives, a survey method is used and a questionnaire has been worked out. Three groups of questions give the opportunity to collect information to find out the students' foreign language background; learners' current goals and level of foreign language competency; the obstacles in the achievement of student's own goals and ways to overcome them. The interpretation of the survey results and the conclusions made allow introducing relevant alterations in the process of foreign language teaching and learning. The survey undertaken makes it possible to develop new methods and techniques of training in foreign languages with regard to modern standards and the needs of learners.

**Keywords:** Engineering students · Learners' needs in foreign language studying Survey

## 1 Context

Globalization processes, as well as internationalization of economies and Russia being integrated into the global community promote the international contacts in the engineering labor sphere. The role of foreign language communication in the activities of engineers is increasing, and the professional communicative foreign language competence of an engineer is becoming more and more significant and important component of the engineer's professional competence.

Meanwhile, the current variety of conditions for an engineer to use a foreign language is determined by a number of factors: specific character of the economy branches, particularities of various engineering activities, growing number of foreign manufacturers, joint ventures and transnational corporations [1]. The variety of professional


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conditions for use of a foreign language leads to diversification of existing professional foreign language communication needs of modern engineers.

Diversification of foreign communicative needs of engineers has been confirmed during the study [2]. The results of the latter show that the needs of engineers in using foreign languages vary depending on the types of engineering activities implemented and the types of organizations they are employed at. The variations of the needs according to the types of engineering activities are mostly connected to the speech genres utilized in spoken and written texts used by engineers. Differences in the needs of engineers depending on the types of organizations can first of all be seen in various levels of engineer's communicative competence in a foreign language required for the purpose of speech activity in a foreign language in organizations of different types.

The results of the survey gave the opportunity to formulate the concept of continuous professional foreign language training diversification in engineering education [1]. According to the concept, diversification is regarded as one of the main directions of its further improvement. It is stimulated by the existing diversification of professional foreign language communicative needs of engineers and is a necessary condition for ensuring its continuity. Diversification of continuous professional training in a foreign language in engineering education provides for differentiation of academic and educational programs in accordance with the variety of use of a foreign language by engineers. Diversification creates conditions for the fullest possible satisfaction of various needs of studying foreign languages on the basis of the participants of the educational process' choosing their educational paths with an unlimited number of combinations of educational programs. With regard to this, diversification of professional foreign language training in engineering education is regarded as both a process and the result of its development.

Further development of the diversified foreign language training system forming the professional foreign language communicative competency of learners varying both in its level and its content requires also the study of engineering students' needs in foreign language learning. More precise identification of learners' motivation, their objectives of studying a foreign language in engineering universities may make the system more efficient.

## 2 Goal

The survey was initiated by the Department of Foreign Languages of Moscow Automobile and Road Construction State Technical University (MADI) and is conducted as a joint Russian-Czech research together with the University Hradec Kralove.

The goal of the survey is to identify the needs of learners of engineering universities in studying foreign languages. To achieve this goal, the following tasks should be solved:

- identifying the students' foreign language background;
- revealing current particular students' needs in studying foreign languages depending on the level of higher education and future careers;
- clarifying problems, the students face in studying foreign languages;
- determining the methods of foreign language teaching the students prefer at tutorials;

- comparing the engineering students' needs in foreign language learning in Russia and the Czech Republic.

The object of the survey is educational activity of engineering universities students. The subject of the survey is engineering students' needs in foreign language studying. The hypothesis of the empirical study was formulated as follows: the needs of students of engineering universities are different depending on the choice of future careers.

## 3 Approach

In order to achieve the research objectives and verification of the hypothesis in this study, a survey method is used. The primary questionnaire method was elected [3] as it has a number of evident benefits. It does not require special training of the interviewers, gives rather accurate results that are conveniently analyzed by SPSS (Statistical Package for the Social Science), etc.

The questionnaire survey technique used included the following the stages of preparation, factual data collection, and analysis of the information obtained.

The questionnaire consists of three sections: an introduction, the basic and the final parts. The introduction of the questionnaire reveals the purpose of the interview and the rules of filling in the questionnaire. The basic part of the questionnaire contains 18 semi-closed type questions, which imply answer options and the opportunity to give a respondent's own viewpoint. The survey was conducted anonymously, but the final part of the questionnaire includes six questions concerning the status of the respondent. Respondents have to specify their university, future profession, country of residence, age of respondents, native language, language spoken in the family, language of instruction at the university.

The basic part of the questionnaire is divided into three semantic blocks. These blocks reflect the analyzed factors such as:

- students' language background;
- actual students' needs in the study of foreign languages;
- methods increasing the effectiveness of learning.

Later the internet version of the questionnaire survey was prepared. It makes possible to cover the maximum range of students.

The second stage of the survey involves factual data collection. It was organized by the Department of Foreign Languages of MADI in April 2016 and has embraced so far 104 students of MADI Management Department specializing in computer science. All the respondents are students of the first year who are trained for the Bachelor Degree: the country of the respondents' residence is Russia; their average age is 18 years old; their native language, the language spoken in their families, and the language of instruction is Russian.

At the third stage of the analysis and generalization of the information obtained, we used SPSS for data processing and analysis.

An analysis unit is elementary and identical to the object of the study. The matrix of the questionnaire includes 19 variables. For better representation of the behavior of the analyzed variable, the graphs of two types were used: pie charts and bar charts.

# 4 Actual Outcomes

## 4.1 Foreign Language Background

Based on the data of the survey the following results were obtained according to the variables (questions) of the first block «language background» . In order to identify clearly language background of each respondent firstly it is necessary to obtain the percentage ratio of responses by each alternative of the question.

In view of the fact that each respondent could choose several alternatives answering the first question *(What foreign language did you study before entering the university?),* the obtained data required a more accurate study. Using SPSS all obtained data were collected in the integrated table and then filtered by probable combinations of options. The filter revealed the percentage ratio of three sub-groups of respondents who had been studying before entering the University: (1) one language, (2) two languages, (3) three languages and more.

It was determined that 100% (104 respondents' answers) of the respondents had been studying English before they entered the university. At the same time, 50% of the respondents had been learning two languages, 44% of the respondents had been learning only one language (English), and only 6% had been learning three foreign languages and more.

As far as the choice of the second foreign language is concerned, German was elected by 30% of the respondents, and in descending order, French was chosen by 22% of respondents, Spanish was chosen only by 3%.

The data give the grounds to make the conclusion that all the students of this specialty have the experience of studying English and more than a half of them have the experience of studying more than one foreign language. German takes the leading position as a second foreign language.

The data obtained on the duration of the foreign language course that is provided by different curricula of secondary educational institutions showed that on this principle we can distinguish two main groups of students. The largest group contains the majority of the respondents (76%), who had studied a foreign language at "a secondary grammar school" for the period from 10 to 11 years or from 8 to 10 years.

The results give the opportunity to conclude that the majority of the students involved in the survey have a long time experience of studying foreign languages that should imply a comparatively high level of foreign language competence.

The question (*What level of foreign language competence did you obtain after the end of the course?*) was aimed at revealing the students' self-assessment of their general proficiency in English before entering the university.

According to the data received the students who had studied only English (40% of the respondents who are taken in this case as 100%) assessed their level as follows:

- 9% at the elementary level;
- 18% at the pre-intermediate level;
- 59% at the intermediate level;
- 14% at the upper intermediate level.

The students, who have experience of learning two foreign languages (50% of the respondents), assessed their skills in English as:

- 12% at the pre-intermediate level;
- 32% at the intermediate level;
- 56% at the upper intermediate and advanced level.

The students, who have experience of learning three foreign languages (6% of the respondents), assessed their skills in English as:

- 33% at the intermediate level;
- 67% at the upper intermediate and advanced level.

Thus, among the respondents who had been studying three foreign languages and more, the prevailing assessment of proficiency level in English corresponds to upper intermediate and advanced levels. Among the respondents who had been studying two languages, the most number of the respondents assessed proficiency in English at intermediate and advanced levels. Based on the results, we can conclude that students having experience of studying more than one foreign language have a higher level of competency in English.

### 4.2 Actual Students' Needs in the Study of Foreign Languages

First of all, it was necessary to find out what foreign language the students are studying now. This question gives the opportunity to a respondent to select only one language, which corresponds to the university curriculum. It turned out that 100% of the total number of the respondents are learning the English language at the moment.

The respondents were also asked how they would assess their own level of a foreign language now. This question helps to define the current level of English as a foreign language studied by the respondents at the University. The results are given below:

- 4% at the elementary level;
- 16% at the pre-intermediate level;
- 46% at the intermediate level;
- 26% at the upper intermediate level;
- 8% at the advanced level.

In correlation with the answers to the above mentioned questions from the section "Language background", that concerned the type of secondary schools, the number of languages studied by the students and the duration of their learning, we can state that the highest level of training and motivation belongs to the respondents who have experience of studying more than one foreign language and studied a foreign language for 10 years or more.

The question concerning the ability of students to use a foreign language let determine their self-assessment of their level of foreign language communicative competence in various types of speech activity: speaking, reading, writing, and listening.

It is revealed that the overall assessment of English proficiency (question7) corresponds to self-assessment of the respondent's level of foreign language communicative competence in various types of speech activity: speaking, reading, writing, and listening. It is necessary to point that the lowest self-assessment of respondents is in speaking skills – both a dialogue and a monologue. These results clarify the problems the students face in studying a foreign language.

The data collected as the answer to the question (*Do you consider that your level of a foreign language helpful for you?)* illustrate whether students think that their level of language competence is enough for various spheres of its application. The majority of the respondents are sure that their current level of language is not quite enough for study/scientific work and for future profession but is quite enough in daily use.

The question about the respondents' motivation in learning a foreign language connects it with the sphere of future application of the language. The results are as follows:

- 58% of the respondents are sure that a foreign language is absolutely necessary their future career;
- 26% of the respondents are sure that a foreign language is necessary some fields of their profession;
- 14% of respondents are sure that a foreign language is desirable for their future career.

An overwhelming number of the respondents (58%) recognize a high need in the foreign language skills. However, the positions "necessary in some fields of their profession" and "desirable" taken together amount about 40% of the respondents, thus, it can be concluded that a considerable number of the respondents can hardly find any fields of practical application of language skills in future.

The question (*What is your goal of studying a foreign language at the university?*) gives answers concerning the objectives the students have when studying a foreign language at the University (several answers choice is acceptable).

The received data illustrate that 70% of the respondents are learning a foreign language at the university for oral communication with colleagues. It is necessary to point out that the desire of the students to be able to participate in future in oral communication has a great obstacle, as their self-assessment of speaking skills is the lowest. That means that at the lessons special attention should be paid to the development of these skills.

At the same time the analysis of this question gives exact information on the spectrum of the students' objectives. The second position is the interest in the improvement of listening skills for understanding cinema and television films. The third position is taken by the skills of reading and translation. In the fourth position we find using foreign language in research.

Other results are as follows:

- 32% of the respondents are eager to conduct personal correspondence;
- 20% of the respondents are interested in participation in international conferences;

- 16% of the respondents need the language to continue study in universities abroad;
- 14% of respondents intend to write articles in international and national journals.

The data collected as the answer to the question (Do you consider your university foreign language course enough for you?) illustrate as follows:

- 49% of the respondents find the university foreign language course quiet enough;
- 29% of the respondents think it is not quite enough;
- 15% of the respondents are sure it is more than enough;
- 7% of the respondents believe it is not enough.

Thus, the foreign language course at the University meets the needs of the majority of the students.

These results are confirmed by the answers to the question (*Are you taking any extra foreign language courses at the moment?*). 36% of the respondents are learning English taking some other courses:

- 62% of the respondents are not taking any extra foreign language courses at the moment;
- 36% of the respondents are taking some self-study course;
- 2% of the respondents are learning the language with a private teacher.

The question (Would you like to pass any international exams?) concerns the respondents' plans to have a certificate to prove his or her proficiency in English passing international tests.

Based on the obtained data, we can conclude that a significant proportion of the respondents (40%) have no objective of taking such exams that in its turn leads to a lack of interest in training and passing such exams.

The concept of the question (*Do you plan to continue training in a foreign university in accordance with your specialty?*) reveals the respondents' plan to study English for academic purposes. 34% of the respondents answered this question negatively, 56% of the respondents do not see any possibility to continue their studies abroad in future and only 10% of them have plans to continue their education abroad.

The answers to the two above mentioned questions show that low interest of the students to international tests and examinations is connected with the fact that they are not planning any academic mobility in the near future and are not aware of the prospects of international professional experience exchange and international research that exist in modern society today. The fact that an overwhelming number of the respondents exclude the possibility of education abroad, may mean that they are quite satisfied with the competencies they acquire at the university.

It was important to find out the opinion of students concerning teaching activities that could help them learn a foreign language better. Answering this question, it was possible to choose several alternatives.

It is obvious that according to the respondents' opinion the most effective activities are to some extend individual activities and can be performed without any support either from a teacher or groupmates, e.g. translation of texts or viewing video content. The second group is formed by the activities of real time communication with one or more partners, e.g. discussions, case studies, and traditional pair work. Quite unexpectedly, one third of the students finds doing exercises in the textbook helpful.

The answers to the question about students' preferences for modern teaching technologies are given below:

- 54% of the respondents prefer electronic textbooks and manuals, demonstrated by a computer and multimedia projector;
- 46% of the respondents like electronic reference books (dictionaries, encyclopedias, etc.);
- 38% of the respondents prefer audio equipment;
- 36% of the respondents find video equipment effective;
- 30% of the respondents prefer interactive conferences and competitions;
- 28% of the respondents like testing programs;
- 28% of the respondents prefer interactive boards;
- 16% of the respondents are fond of DVD and CD discs;
- 12% of respondents prefer distant learning.

No wonder, that most of the respondents choose modern digital technologies and electronic devices such as electronic textbooks and manuals, multimedia projectors, electronic reference books (dictionaries, encyclopedias, etc.). But it is very important, that only 12% of the respondents find distant foreign language learning effective, realizing the significance of face-to-face communication in acquiring language skills and competencies.

The idea of the question (Do you consider regular tests necessary for improvement of the quality of foreign language learning?) was to find out the students' attitude towards the necessity of intermediate check-up (test) of foreign language learning.

- 8% of the respondents believe that they are extremely necessary;
- 22% of the respondents are sure they are necessary;
- 38% of the respondents find them desirable;
- 32% of the respondents think that they are not necessary.

Analyzing these data, we can be concluded that 2/3 of the respondents (answers "extremely necessary", "necessary" and "desirable" taken together) find regular testing useful for them. All the conclusions concerning methods and techniques of instruction should be taken into account in the teaching process.

## 5 Conclusions

Foreign language training of university students should take into account professional needs of graduates and interests of students as well. The diversified system of continuous professional foreign language training in engineering education is based on the diversity of professional needs of engineers. Its further development requires research of learners' needs in foreign language studying as well.

For that purpose, a special survey was undertaken in Moscow Automobile and Road Construction State Technical University (MADI) in order to find out foreign language learning needs of the Management Department students specializing in computer science. The results of the survey and their interpretation allow to make a number of conclusions concerning the students' language background, actual students' needs in the study of foreign languages and methods increasing the effectiveness of learning.

As far as the students' language background is concerned all the students of this specialty have the experience of studying English and more than a half of them have the experience of studying other foreign languages. German takes the leading position as a second foreign language. The majority of the students involved in the survey have a long time experience of studying a foreign language, which may imply a comparatively high level of their foreign language competency. The analysis shows that the students having experience of studying more than one foreign language assess their level of competency in English higher than others and demonstrate the highest level of training and motivation. Quite unexpectedly for applicants of technical universities 20% of the respondents passed All-Russian State Exam in a foreign language to prove their level of language proficiency.

As far as current students' needs in foreign language studies are concerned more than 80% of the students are sure that a foreign language is either absolutely necessary for their future career or is necessary in some fields of their profession. Realizing the necessity of mastering a foreign language the majority of the respondents think that their current level of language is not quite enough for three spheres: education, for scientific work and for their future profession but it is quite enough in daily use. The majority of the students (90%) are not planning to continue their studies abroad in the near future. This fact may explain that as a result the students have no objective of taking international exams in a foreign language. It can be recommended to give more information of the advantages of international exam certificates to raise interest to preparation for them.

The majority of the students considers the university language course to be either more than enough or quite enough for them and is not taking any extra foreign language courses at the moment.

Among the purposes of foreign language learning, the students name first of all oral speech including oral communication with colleagues, participation in international conferences and business communications. It is very important that at the same time the students assess their ability to speak in the form of both a dialogue and a monologue at the lowest level of the language competence. That fact requires introducing necessary changes in the process of teaching. Among the activities that may help students they name text translation, discussions, case studies, listening to audio recordings, pair work. Quite unexpectedly, one third of the students finds doing exercises in the textbook helpful.

According to the students' opinion, the most efficient technologies include electronic textbooks and manuals, multimedia projectors, electronic reference books, web educational resources, audio and video equipment, interactive conferences and competitions.

The results of the survey allow work out new teaching materials and influence the teachers' choice of classroom activities and methods. The survey should embrace students of different departments, universities in Russia and in Czech Republic to reveal mainstream tendencies to be taken into account in the design of the diversified system of continuous professional foreign language training in engineering education.

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## References

1. Polyakova, T.Y.: Diversification of continuous professional training in engineering education. Theory and technology of professional education. Bull. MSAU **3**(42), 31–34 (2010). Полякова ТЮ: Диверсификация непрерывной профессиональной подготовки в инженерном образовании. Теория и методика профессионального образования. Вестник ФГОУ ВПО МГАУ, МГАУ, №3(42), с. 31–34 (2010)
2. Polyakova, T.Y.: Variety of engineers' needs in the foreign language usage as a basis for their training diversification. Soc. Behav. Sci. Procedia **214**, 86–94 (2015)
3. Yadov, V.A.: The Strategy of Sociological Research. Description, Explanation, Understanding of Social Reality, 6th edn. Akademkniga, Dobrosvet, Moscow (2003). 596 p. Ядов ВА: Стратегия социологического исследования. Описание, объяснение, понимание социальной реальности. 6-е изд, Москва: Академкнига; Добросвет, с. 596 (2003)

# Wither Textbooks in Language Teaching? A Closer Look at Teaching German as a Foreign Language in Sri Lanka in the Digital Age

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**Abstract.** Textbooks continue to be an integral part of language teaching and a main resource available to teachers and students. In this digital age the presentation of textbooks also have undergone many changes. In addition to the workbooks, audio CDs and teachers' guides, the books are accompanied by CD-ROMs and additional downloadable material from the publishers' sites. Nevertheless, there are several limitations in the textbooks especially when teaching advanced learners. Thus, the teachers opt for online material available today for language teaching. This paper examines whether the textbooks are becoming obsolete in this digital age with data obtained from Teaching German as a Foreign Language in Sri Lanka.

**Keywords:** Foreign language teaching · Foreign language textbooks
Web-based teaching · Learner autonomy

## 1 Introduction

The aim of any language teacher is to find more effective ways of teaching to enhance student performance. Textbooks have been an integral part of language teaching for centuries while undergoing many changes during the course of time, adapting to latest teaching methodologies. "Textbook as a strong tool for teaching and learning" of foreign languages (Latifi and Rahmatipasand 2015:1) continues to be one of the main resources available to students and teachers alike [12, 13]. With the advancement of technology many supplementary material have been developed to complement the traditional textbook. Thus, in addition to the workbooks, teachers' guides and audio CDs, today the publishers develop whiteboard versions, supplementary online exercises, DVD-ROMs and downloadable material to complement the textbooks.

While continuing to be an essential part in teaching languages at beginner level, textbooks have shown many limitations when teaching advanced learners. Since the material included do not always comply with the learning outcomes or interests of the learner, many foreign teachers opt for textbook adaptation by developing additional material to suit the learners or rely on online resources to design more effective, learner friendly lessons. Thus, the key role of textbooks in foreign language teaching appears


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to be diminishing today in comparison to a few decades ago. This paper examines whether the textbooks are becoming redundant in this digital age with data obtained from integrating online material in teaching advanced learners of German as a Foreign Language at the University of Kelaniya, Sri Lanka.

## 2 Significance of the Study

The University of Kelaniya has the only dedicated department of study for foreign languages in Sri Lanka including French, German, Russian, Chinese, Japanese and Korean, offering three year and four year Bachelor programmes and postgraduate programmes with over 1200 students. Many studies have been conducted in integrating Computer Assisted Language Learning (CALL) in Teaching German as a Foreign Language since 2004 with significant results showing marked improvement in student performance [2–9]. With over 400 students offering German as Foreign Language (*Deutsch als Fremdsprache*) for the three year Bachelor Degree, German Studies (*Germanistik*) for the four year Bachelor of Arts Honours Degree and the two year Certificate Course in German, the results of previous studies in CALL in the language classroom have immensely benefited the academic staff and the students alike [2–9]. The learning traditions of Sri Lanka show a strong inclination towards textbook based learning and written examination based assessments [3, 10]. Thus, the teachers as well as learners of any subject taught at school level including second and foreign languages tend to become dependent on textbooks as the sole provider of knowledge and information. As a teacher of German as a Foreign Language there is no dearth of textbooks and supplementary material developed in Germany with many works being revised and updated on a regular basis. However, no single textbook is able to cater to the learning outcomes of a course. Therefore, textbook adaptation is required to suit the selected group of learners, which adds an additional burden on the teacher. Furthermore, the material including audio and video data that accompany the textbook are not always authentic, representing real life situations [11]. Thus, a true picture of the native speaker environment may not reflected through the textbook and accompanying audio video material. As far back as 1995 Boxer and Pickering pointed out the shortcomings in artificially developed material in textbooks for second or foreign language teaching [1]. "Only through materials that reflect how we really speak, rather than how we think we speak, will language learners receive an accurate account of the rules of speaking in a second or foreign language" (1995:56)

The Government of Sri Lanka provides all state schools with textbooks free of charge. However, the university students have to purchase the textbooks at a fairly high cost if it is prescribed for a foreign language. At present, only the first year students at the university are required to purchase a textbook for German while the students in second, third and fourth years are provided with handouts from different textbooks. With the advancement of technology, many language learning portals and online teaching material are available today where some material can be directly applied, while others can be adapted for the lessons as required. Hence, it was significant to explore the effectiveness of integrating online material in the language classroom by deviating from the dependence on a particular textbook or selections from many. Thus, this study examines how effective web-based teaching is for advanced learners of German in contrast to textbook based teaching. The remarkable improvement in online access available to the students and teachers at the university during the past few years provided the necessary impetus to embark on this study. Free Wi-Fi access is provided at university premises and student hostels, lecture halls are provided with internet access and several computer laboratories were made available for teaching purposes with round the clock supervision by competent technicians. The Government policy to introduce an interest free loan scheme for university students to purchase laptop computers since 2016 also provided students with more opportunities for online access outside the language classroom.

## 3 Approach

The aim of this study was to integrate suitable online teaching material to enhance student performance and language competency without depending on textbooks. Three course units in the four year Honours Degree Programme in German Studies *(Germanistik)* and one course unit in the three year Bachelor of Arts Degree Programme in German as a Foreign Language *(Deutsch als Fremdsprache)* were selected for the study during the past three academic years. The students were from third and fourth years of study at the university. The course units were based on Oral and Written Communication Skills, Analysis and Interpretation of Non-literary Texts and Discourse Analysis, spanning one academic year. Since the student sample had mastered the grammatical structures of the language during the first two years of study at the university, the aim of the selected course units was primarily to improve their language competency, oral and written expression, vocabulary, cultural awareness, world knowledge, understanding and expressing oneself in an authentic native speaker environment and the ability to reflect on one's own culture. Thus, it was imperative that the students are exposed to native speaker environment for more effective outcomes at the end of the course units. The language competency level of the students ranged from A2 to C1 of the Common European Framework of Reference (CEFR) according to the study programme and the relevant course unit. These courses were previously conducted by adapting material from several textbooks including *Em Neu, Aspekte, Stufen International, Menschen, Mittelpunkt* and *Ziel* [5]. During the three academic years relevant to this study, the teaching material solely depended on online sources i.e. authentic material including online newspaper articles, audio and video material and online exercises. Different online teaching material were selected according to the relevant theme and topic of the lessons. The primary source of material was from the website *'Deutsch Unterrichten'* of the Deutsche Welle (www.dw.com/de/deutsch-lernen) that provides audio and video material, news items developed as classroom worksheets, language training portal and tele-drama series for Teaching German as a Foreign Language. The audio and video material and the worksheets with latest news items are updated regularly, while the archive provides access to material as far back as 2008 where material relevant to virtually any topic on culture and lifestyle in Germany is available. In addition, material from the Goethe Institute, different German television channels, newspapers and magazines were selected. The number of students involved in the study comprised around 75 in each academic year who followed the selected compulsory course units.

Different sources were utilized to collect data for the study. Feedback from the students involved in the study on the effectiveness of online material in the language classroom against the use of textbooks; interviews of teachers of German in the university and a sample of students who were in first and second years on their view of having a prescribed textbook for German provided data for this study. A sample of school teachers in German were also selected for the study to find out their views and experiences on use of online material in the language classroom. The academic staff and the school teachers responded to the queries on the frequency of the use of textbooks according to competency level of the students, whether textbook adaptation is applied, how often online resources are integrated in their lessons, their views and observations on working with online material. The students from first to fourth years responded to the queries on their views on the importance and benefits of textbooks in the language classroom and use of online material.

Furthermore, results of the end of course examination of each course unit during the past academic years since 2008 were analysed to assess the effectiveness of integrating online teaching resources [5]. Thus, the results from previous academic years of teaching primarily with textbook adaptation during 2008–2009 as depicted in Fig. 1, the improvements in performance after integrating web-based learning along with textbooks from 2010 to 2014 (Figs. 2 and 3) and the student performance during the past three academic years solely with online resources (Figs. 3, 4, 5, 6 and 7) were taken into consideration.

## 4 Actual Outcomes

Web based learning was integrated into the course units of German during 2007–2009. However, the use of textbooks for lessons continued along with the use of material available online. The Fig. 1 below shows the average performance of students in the three year degree programme during this period where more emphasis was given to textbook based learning [5]. There was less exposure to web-based material enhance their language competence and cultural awareness due to lack of facilities available at university premises for students to go online for learning purposes. The course units in German start with the code GERM followed by the number assigned to the unit. Third year units start with the digit 3 and the fourth year units start with the digit 4.

As seen in Fig. 1. The average performance at the course unit GERM 33023 Analysis and Interpretation of Non-literary Texts in the three year bachelor degree programme showed that 15% had failed obtaining below 24 marks, 20% had secured a ‘D’ pass between 25–39 marks, around 50% had managed to secure a ‘C’ or ‘C+’ Grade with 40–49 marks, and only 15% had obtained grades higher than a ‘C+’. Out of this 15%, only 5% of the students had managed to obtain over 70% [5].

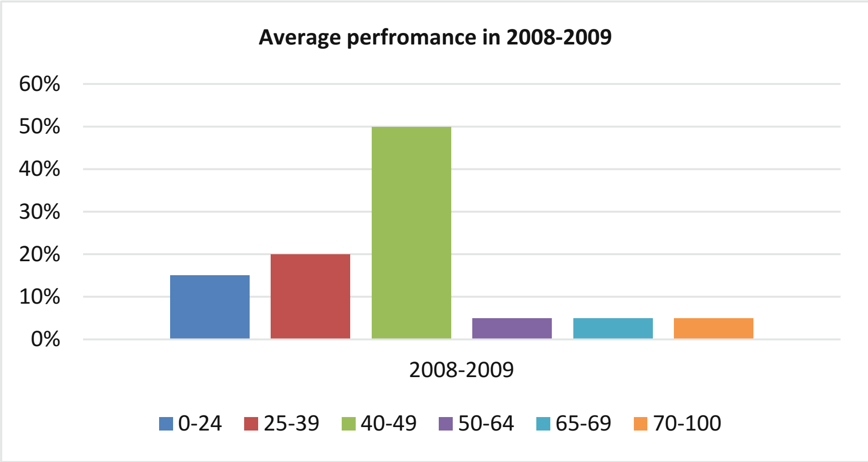


**Fig. 1.** Performance at three year degree programme GERM 33023 in 2008–2009

With the gradual improvement technical facilities available to the students at the university to use online material, more options were available to enhance learner autonomy. By the year 2010 a classroom equipped with internet facilities was provided to conduct the course unit GERM 33023. The students could go directly online and find information on their own to the tasks assigned. As seen in Fig. 2. Remarkable improvement was shown in their performance at assessments and end of course examinations along with their ability to work more independently enhance their language competence and cultural awareness [5].

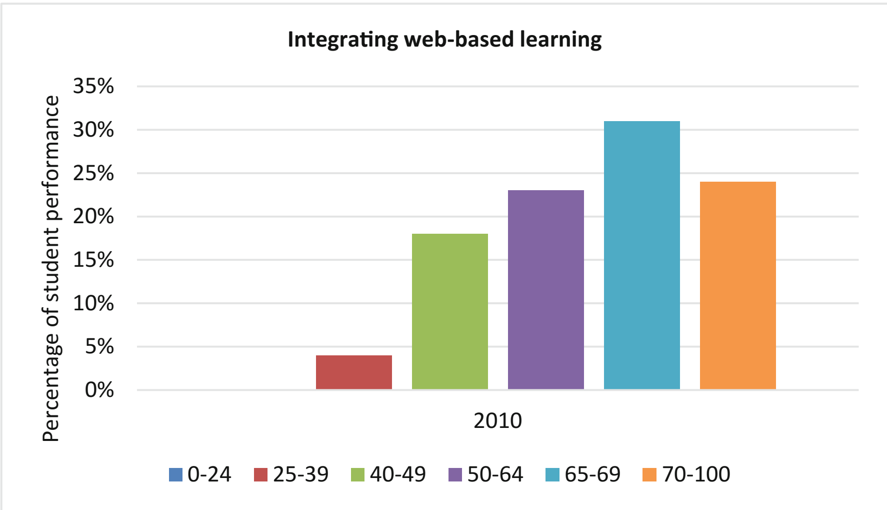


**Fig. 2.** Performance since integrating web-based learning

During this period the Wi-Fi facilities were not available at the university or the hostel premises. Hence, the students had hardships in accessing material online outside the university premises. The majority of the students at the university hail from low income groups who could not afford outright purchase of personal computers or bear the cost of monthly internet charges. However, the improvement in results provided an impetus to the author to further explore the integration of web-based learning into the language lessons.

Gradually the IT infrastructure at the university vastly improved with more IT laboratories for the students of the Faculties of Humanities and Social Sciences and fast access to the internet. Thus, by 2015 access to online resources inside and outside the classroom were freely available to the students with Wi-Fi coverage at university and student hostel premises. Figure 3 depict the student performance of the selected course units in 2014 with 60% integration of online resources and 40% use of textbook adaptation.

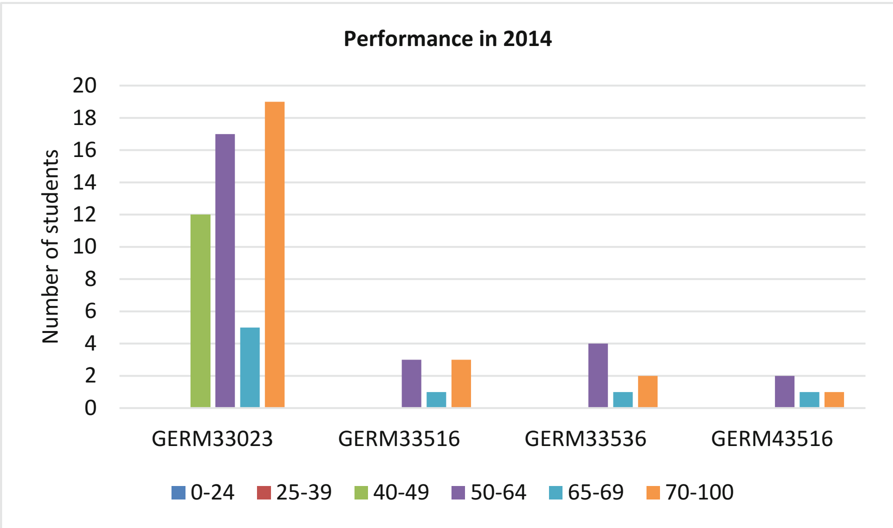


**Fig. 3.** Performance at BA three and four year degree programmes in 2014

With the vast improvement of IT facilities at the university from the year 2015, the selected course units were designed and delivered entirely through online resources. Firstly, the free online platform www.classjump.com provided the platform for designing the lessons [2]. With the development of the online learning platform for Teaching German as a Foreign Language in 2016 - *Deutsch für Uni Kelaniya* - at www.openlearning.com, the use of online material proved to be even more effective [2]. Material relevant for the day were uploaded prior to the commencement of the lesson and students were given half an hour for preparatory work on the theme. Links to online exercises and additional material were also made available through the portal for further study after the lesson.

While all the selected course units were built on web-based material, it was evident during the analysis of the study that the success at examinations, student motivation, language competency and learner autonomy showed remarkable improvement in comparison to previous years of textbook based teaching. For instance, the students in the fourth year of study in the last two academic years achieved 100% in reaching the maximum Grade Point Average (GPA) of 4.0 in comparison to around 25% previously, while the third year Honours Degree students showed a 100% achievement in securing GPA of 4.0 in 2015 and 2016 and 80% in 2017 against 43% previously. The students in the three year degree programme also showed a marked improvement in their achievement at the end of course examination with 51% achieving a GPA of 3.5 or above against 37% in 2014. The two batches of students of German Studies who graduated in 2016 and 2017 achieved a GPA of 4.0 overall, thus qualifying for the highest achievable grade of First Class Honours.

The Figs. 4, 5, 6 and 7 provide a clear view of the improvement of student performance over a period of three years since switching over entirely to online resources for teaching purposes. Figure 4 depict the student performance of the three year Bachelor Degree Programme (*Deutsch als Fremdsprache*) while Figs. 5, 6 and 7 present the results of the four year Degree Programme (*Germanistik*).

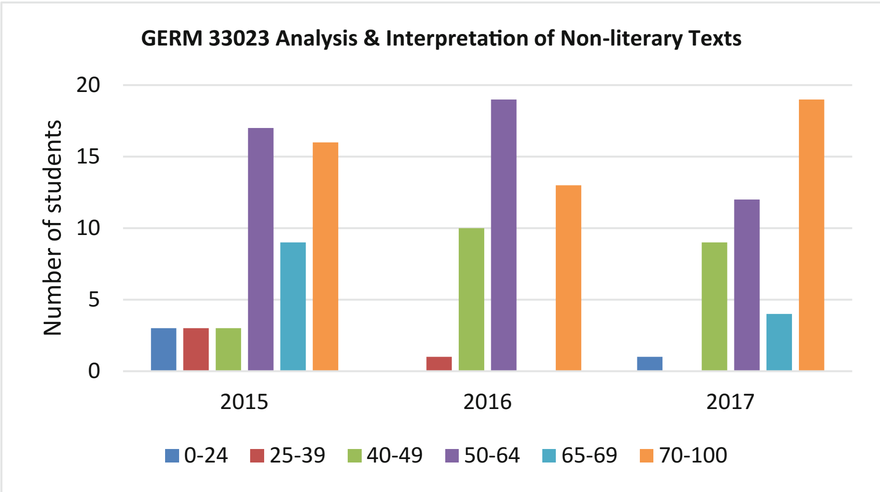


**Fig. 4.** Performance at BA three year degree programme since 2015

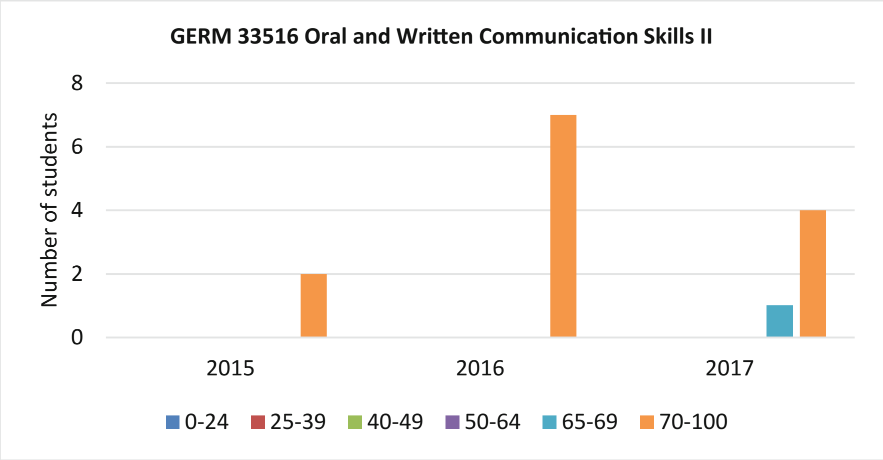


**Fig. 5.** Performance at four year degree programme GERM 33516

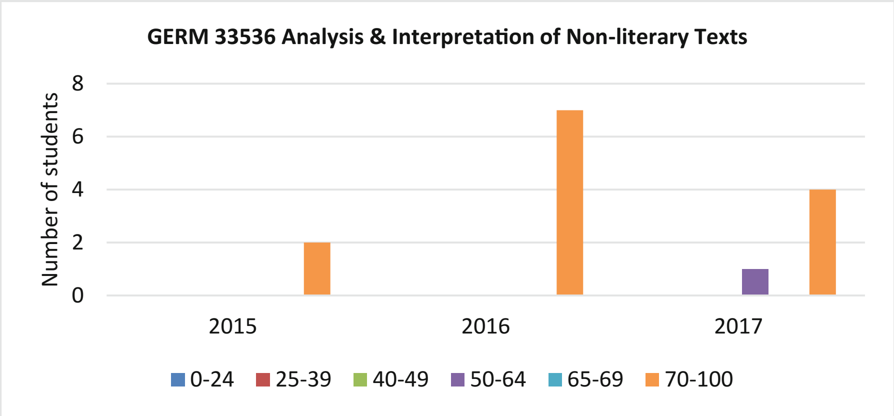


**Fig. 6.** Performance at four year degree programme GERM 33536

Figure 7 shows the 100% achievement of GPA of 4.0 which was also seen in the overall results of the students in 2016 and 2017. Thus, it is evident that the deviation from textbook dependency towards online resources in selected course units has paid dividends by transferring the success to other course units compulsory for the students of the Honours Degree Programme in German Studies too.

The positive feedback from the students on the use of online material include their inclination to learner autonomy and motivation to explore further for relevant online material to improve their language competency and cultural awareness. The guidance provided by the online platform with selected material for each lesson provided them with more resources than a single textbook or a selection from different textbooks could provide. The academic staff members were of the view that the textbooks are of importance at beginner level. However, they reiterate that the prescribed textbook also need additional material to suit the learner needs and pace of learning. Furthermore, they believe that online material offer more options, freedom to select appropriate material and opportunity to provide a more authentic picture of Germany and German speaking countries to the students. The school teachers believed in the advantages of online sources against the textbook. However, practical difficulties in integrating web-based teaching due to lack of infra-structure facilities were pointed out. They were not conversant in using online resources, lacking experience and exposure. The school teachers also expressed their concern over shifting from the textbook to web-based teaching due to the fear of not being able to cover the designated curriculum and prepare students for national examinations.

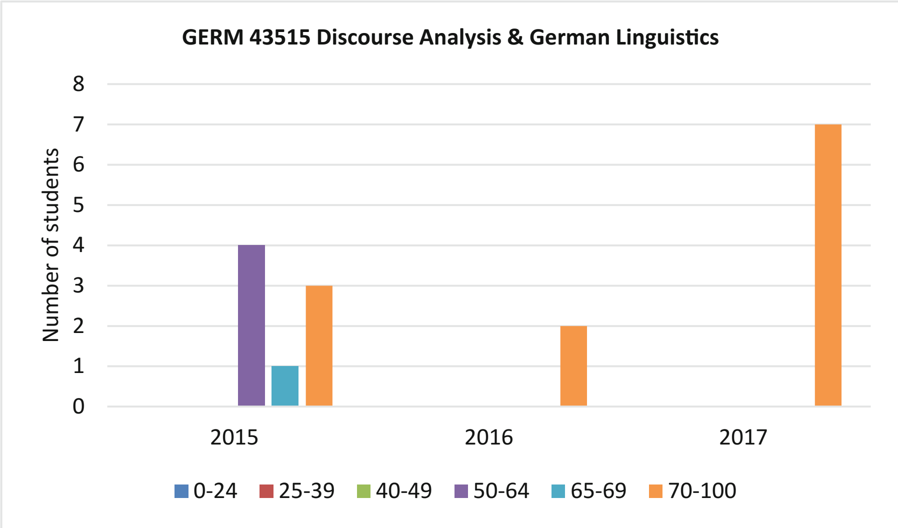


**Fig. 7.** Performance at four year degree programme GERM 43515

The majority of the first year students observed that the prescribed textbook is pivotal as it gives them assurance, a sense of security and confidence in learning German as a beginner. The second year students were split in their opinion with only 53% finding the use of a prescribed textbook as essential. The third year students in the three year degree programme believed that a textbook provides a sense of security to weak students. However 88% agreed that online material provided more variety, a true picture of German speaking countries and more opportunities to access the material at their own pace. The Honours Degree students in third and fourth year students were 100% for online teaching resources through the learning platform as it offered them autonomy, variety and abundance of material to enhance all four skills of language competency.

## 5 Conclusion

The results of the study based on three academic years show that advanced learners of German are able to enhance their language competency entirely based on online learning resources and that the textbook no longer needs to be an integral part of the teaching process. The online resources are more up to date, authentic, easily accessible, cost effective and offer more variety in comparison to the textbooks. Thus, the question arises whether the textbook is losing its indispensability in this digital age. Nevertheless, the online material provided to the students need to be carefully selected to focus on reading, writing, speaking and listening skills of the students as the modern day textbooks address the four skills of language competency albeit they may not provide sufficient training in all competencies. The supplementary material of a textbook including workbook, audio CDs and DVD-ROMS also incur additional expenses, which is beyond the means of an average university student in Sri Lanka. However, it is recommended that the textbook is used as an important element at beginner level of language teaching as it offers assurance to students, provides support for novice teachers and an opportunity to monitor progression of the learning outcomes. Moreover, discussions with the language teachers in schools brought into light the difficulties in using online material due to lack of resources available in schools. It is also a daunting task to motivate the textbook inclined teachers and students to deviate from the textbook culture in schools as all other subjects are taught solely based on prescribed textbooks.

## References

1. Boxer, D., Pickering, L.: Problems in the presentation of speech acts in ELT materials: the case of complaints. ELT J. **49**, 44–58 (1995)
2. Premawardhena, N.C.: Developing a common learning platform for foreign language teaching. In: Auer, M.E., Guralnick, D., Uhomoibhi, J. (eds.) Interactive Collaborative Learning: Proceedings of the 19th ICL, vol. 2. AISC. Springer, Cham, pp. 369–382 (2017)
3. Premawardhena, N.C.: ICT in the foreign language classroom in Sri Lanka: a journey through a decade. In: 10th World Conference on Computers in Education (WCCE 2013), 2–5 July 2013, Torun, Poland, pp. 223–224. Nicolaus Copernicus University (2013)
4. Premawardhena, N.C.: Introducing computer aided language learning to Sri Lankan schools: challenges and perspectives. In: 15th International Conference on Interactive Collaborative Learning and 41st International Conference on Engineering Pedagogy (ICL & IGIP), Villach, Austria (2012)
5. Premawardhena, N.C.: Enhancing student performance through web-based learning and online teaching tools at Sri Lankan universities. In: 14th International Conference on Interactive Collaborative Learning (ICL & VU 2011), Piestany, Slovakia (2011)
6. Premawardhena, N.C.: Creating a native speaker environment in the foreign language classroom through web based learning. In: 13th International Conference on Interactive Computer Aided Learning (ICL 2010), Hasselt, Belgium, September 2010
7. Premawardhena, N.C.: Creating a native speaker environment in the foreign language classroom through web based learning. In: ICL 2010, Hasselt, Belgium (2010)
8. Premawardhena, N.C.: New horizons in language learning through web-based teaching. In: ICL 2009, Villach, Austria (2009)

9. Premawardhena, N.C.: From dependent learning to leaner autonomy through web-based teaching. In: ICL 2008, Villach, Austria (2008)
10. Premawardhena, N.C.: Lerntraditionen im Vergleich: Sri Lanka und Deutschland. In: 14th International Congress on Education and Information Technology, Karlsruhe, Germany (2006)
11. Gak, D.M.: Textbook – an important element in the teaching process (2011), epub.ff.uns.ac.rs/index.php/MV/article/download/771/781. Accessed 10 April 2017
12. Latifi, M., Rahmatipasand, S.Z.: The needs of teachers and students to a foreign language textbook. Indian J. Fundam. Appl. Life Sci. **5**(S2), 69–73 (2015). ISSN: 2231–6345
13. Richards, J.C.: The role of textbooks in a language program (2001). http://www.professorjackrichards.com/wp-content/uploads/role-of-textbooks.pdf. Accessed 10 April 2017

# Study and Development of a Classroom Management System - Application for Programming Language Labs

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**Abstract.** In this work, we are interested to improve the pedagogical accompaniment of students in programming language labs by implementing a classroom management software. It consists of two applications. The teacher application allows teacher to create a classroom, connect student computers to the classroom, collect student works periodically in order to help them and to have an overall view of the student's works progress. In addition, teacher can temporarily lock the student computers to attract student's attention when he gives explanations. With this software, teacher does not move from one student to another. So, the moving time will be spent to improve student learning. The student application allows student computers to connect to teacher application, receive the comments and remarks sent by teacher. Each student can also send his final work to teacher at the end of the class. Thus, students do not need the internet connection or a USB key to return their work.

**Keywords:** Computer science · Classroom management system
Programming language labs

## 1 Introduction

Computer labs became an integral part of educational institutions and especially universities and it takes more importance in the field of computer science. Inside computer labs, teacher accompanies the students in doing their works. This accompaniment takes various forms: orientation, help and correction of errors. However, with the large number of students in some universities, computer labs suffer from the low average time that a teacher appropriate to a student because teacher loses many time when he moves from one student to another. So, it has


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become difficult for a teacher to ensure a good pedagogical accompaniment of students during a period often limited to 90 min. In addition, during teacher's intervention with a student, the other students and especially who are waiting for teacher's intervention will remain in a blocking situation. Thereafter, they will not have enough time to complete their work and this negatively affects the quality of student learning.

In order to tackle those obstacles encountered in the traditional practice of computer lab sessions, software engineers introduced several solutions in order to help teachers to have a much better control and management over the class and also provided other communication tools (e.g. text messaging and file transfer) for a much better and faster communication between teacher and students. These solutions are known as the classroom management system.

This paper is organized as follows: Sect. 2 describes briefly the related work. Section 3 provides the implementation of the proposed software while Sect. 4 presents the experiments of this research. Section 5 concludes the paper.

## 2 Related Work

Classroom management is considered an essential part of the teaching and learning process. It refers to the actions, methods, strategies and skills that teachers use to maintain order in a classroom and ensure student's learning success [1]. Classroom management is connected to a process of organization and conducting a class that includes time management, student's involvement, student engagement, and classroom communication [2].

A classroom management system is a software solution that was specially designed for effective teaching, managing, controlling and monitoring students in networked classrooms [3]. Many classroom management systems have been proposed by many developers, the famous and commonly used by the community are presented in this section.

iTALC (intelligently Teaching And Learning with Computer) is an open source didactic software. It is used for monitoring classroom computers. It is conceived and developed by T. Doerffel with Qt/C++ [4]. iTALC is elaborated for computer work at school but it can be used in other learning environments. It provides a lot of tools to teachers, such as [4]: see the student's screens and make snapshots, access to the student's desktop if a student need assistance or help, this student sees all the actions performed by the teacher, show the teacher's screen on all student's computers to improve student follow-up, lock student's screens for giving attention to teacher explanations and send text messages to students.

TKontrole is an open source application developed by V. Verdon using Tcl/Tk [5]. It is used for monitoring a set of computers by sending regular screen shots of student's screens to the teacher's computer. TKontrole has the same functions as iTALC but it offers other operations such as: continuous recording of student's screens in image format, blocking access to the Internet and prohibiting the execution of some software programs that do not relate to learning session.

NetSupport School [6] is a paid software solution for schools. It provides to teachers many features such as [7]: monitoring the student's screens, interacting with students in order to work collaboratively, delivering lesson content to all student, ensuring that all students focus when teacher gives explanations by locking their screens, blocking USB/CD devices and collect work from students.

Faronics Insight [8] is a market-leading solution. It manages and secures complex IT environments. It can be used in educational institutions, libraries and government organizations. It is composed of teacher's and student's consoles. The teacher is able to perform the following operations: discover student computers, display a thumbnail of student screens, limit access to the web, stop lunching some software, send messages to students, receive questions from students, remote control of student computer and send training examples to students.

Lenovo LanSchool [9] is a simple classroom management software that keeps student more engaged in learning. It promotes collaborative learning and minimizes distractions. This software has several features, among them: monitoring students by seeing student's screens, using chat function to communicate and help students to do their project, teaching more effectively by showing the teacher screen on the student's computers, broadcast quick quizzes and share results with the students, using remote control for quick assistance to students and blanking all student screens to focus student's attention to the teacher explanations.

Netop Vision [10] is a paid classroom management software. It gives many tools to control student's computers, keep an eye on student's works, present lessons by sharing the teacher's screen, supervise student's works by observing the thumbnail image of each student's screen, assist and help students by remote access to their computers, blank student's screens to ensure that they are paying attention to teacher's explanations and control student's Internet use.

## 3 Proposed Approach

All the software described in the previous section have several features that fulfil the needs of an effective classroom management system, but they still do not provide all the features we need. Some of them do not support the ability to send text messages from student to the teacher, e.g. TKontrole and iTALC. While the other four systems provide this feature but it stays poor because they do not have a separate window for messaging to allow the teacher and the student to manipulate the list of messages more freely (e.g. copy the message text). In addition, iTALC and TKontrole have poor features compared to other paid solutions. So, their user interfaces seem much easier to use. Furthermore, another lack in these two applications is the way they connect to student computers which is difficult. However, the paid applications have a lots of features but their user interfaces are much complex. On the other hand, these software are too expensive.

At our university and especially in our department, there are many programming language labs and the number of students can be greater than 30 in each classroom. In addition, the surface of the classroom is $14.4 \times 4.2\,\mathrm{m}^2$. So, the programming language labs suffer from the low average time that a teacher appropriate to a student because he spends a lot of time while moving around the class (see Fig. 1a). As consequence, almost half of the students are waiting for teacher's intervention while remaining in a blocking situation. Even with the second scenario of teacher movement (see Fig. 1b), the teacher can not verify if the students have taken into account his remarks to complete their works. So, students who have completed their work would like the teacher to check their work but unfortunately the time of the lab is finished. However, other students claim that they were in a blocking situation for more than one hour.

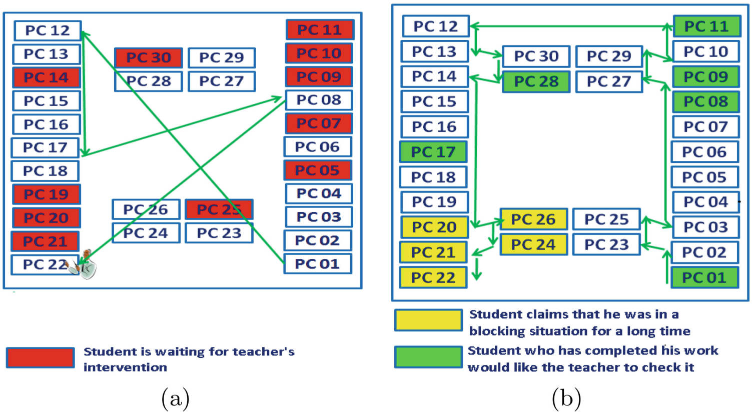



**Fig. 1.** Two scenarios of teacher movements around the class.

For these reasons, we have developed a classroom management software not to control only the students but to help the teacher in the pedagogical accompaniment of students in doing their works. This system contains the most features of the software mentioned above but new features have been added such as: providing a better messaging mechanism where teacher/student can see the list of the received and sent messages and copy the content of the message, the teacher can access periodically to the student workspace and download files from it, then edit the files and upload them back to the student workspace. So, the teacher can obtain an overall view of the student's works progress. However, he can not obtain it with the classical pedagogical accompaniment. Moreover, at the end of the lab, the students can send their work to the teacher computer instead of using USB drives or Internet connection.

This software consists of two applications: one for the teacher and another for the students. It is based on a Client/Server architecture which designates a set of computers related within a network. Some computers will provide services (server) while the others (clients) are able to request (consume) these services. These two applications use Virtual Network Computing (VNC) [11] which provides many tools such as displaying the screen of another computer and controlling remotely another computer.

### 3.1 Teacher Application

The teacher application allows to create a classroom, add student computers to the classroom, connect the student computers to the created classroom. When the connection is established to a classroom, a square shaped graphical component will be added to the graphical interface in order to show a thumbnail of the student computer (see Fig. 2). The teacher can also open student's workspace folder, download student's workspace files, comment them in order to guide and help them to correct their errors, upload the commented files to the student's workspace (see Fig. 3). In addition, the teacher can temporarily lock the student computers to attract student's attention when he gives explanations. This feature is necessary because the students do not follow the teacher's explanations when they work with computers. With this application, the teacher does not move from one student to another. So, the moving time will be spent to see the progress of the student's works and if they have taken into account the comments

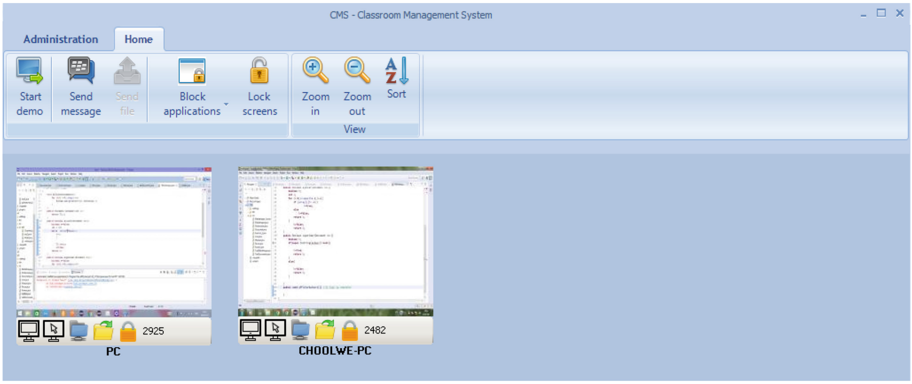



**Fig. 2.** Teacher graphical interface.

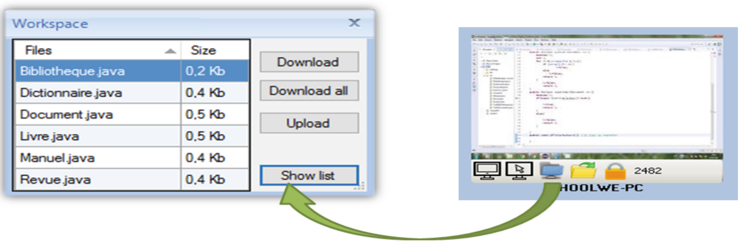



**Fig. 3.** Explore student's workspace.

that he has already sent them. The graphical interface of teacher application is presented in Fig. 2.

### 3.2 Student Application

The student application only consists of a single window. It allows to connect the student's computer to the teacher application, select the student's workspace folder which include student's work, send messages to the teacher, receive messages from teacher, receive the comments and remarks sent by the teacher. In addition, it allows students to send their final works to the teacher at the end of the lab. The graphical interface of student application is presented in Fig. 4.

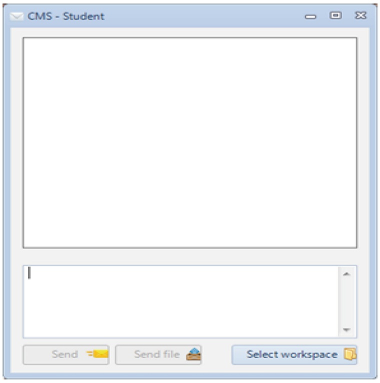



**Fig. 4.** Student graphical interface.

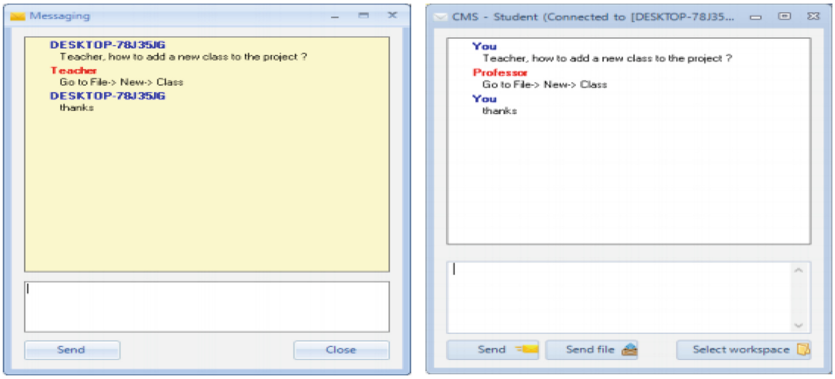
## 4 Experimental Results

In order to test the developed software, we have performed two experiments on two programming language labs which are described in Table 1. In these lab sessions, students have used their laptops which have been connected to a single Wireless network controlled by the teacher computer.

The teachers have tested all the features of the system: receive messages from students and send responses (Fig. 5), lock student's screens when they give explanations, broadcast teacher's screen on student's computers, send training examples to all students, download student's workspace, comment files and upload them to student's). The teachers are satisfied with this software because it eliminates the need for a video projector and ensures that students are paying attention to their remarks and they can help students many times in one lab session.

**Table 1.** Description of programming language labs

| | First test | Second test |
|---|---|---|
| Level of study | First year Master's degree on networks and distributed systems | First year license on computer science (commun core) |
| Course | Distributed algorithms | Introduction to object-oriented programming |
| Number of students | 8 | 10 |
| Programming language | Java | |
| Development environment | Eclipse | |




(a) (b)

**Fig. 5.** Messaging window: (a) Teacher side, (b) Student side.

At the end of the tests, we have asked the students to give us their opinion about this software. The most of students have appreciated this software and they are motivated to use it in the next year. They have enjoyed the reception of the commented files (see Fig. 6) because they did not wait too long to get help from the teacher. In addition, the students seating at the back of the classroom have appreciated to see the teacher screen on their computers rather than to follow the projection that is done by video projector.

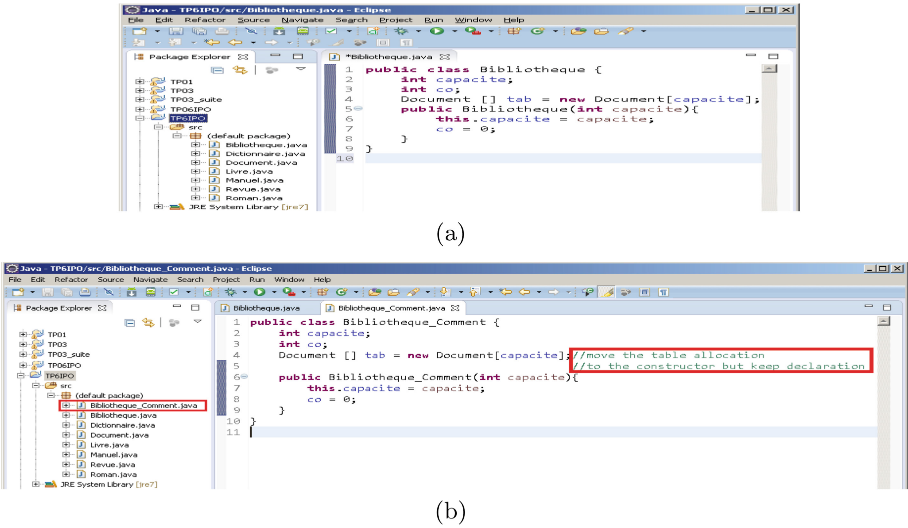



**Fig. 6.** (a) Initial student's workspace, (b) Workspace after receiving teacher comments.

## 5 Conclusion

With the great number of students in some universities, programming language labs suffer from the low average time that a teacher appropriates to a student. Also, teacher spend more time during his movement around the class to check each students separately. To overcome these limitations, we have proposed a classroom management software to fill in more gaps by combining features of the existing systems and adding new features that will be greatly helpful. These new features consist of offering a good communication mechanism by using a separate window for messaging where teacher/student can view all the messages and copy the content of a message, providing file sharing in both directions for teachers and students, allowing teacher to view student's workspace while working and he can also download workspace files, edit them and upload them again to the student's workspace.

## References

1. Rufai, M.M., Alebiosu, S.O., Adeakin, O.A.S.: A conceptual model for virtual classroom managment. Int. J. Comput. Sci. Eng. Inf. Technol. (IJCSEIT) **5**(1), 27–32 (2015)
2. Schneiderov, P.: The effective classroom management in young learners' language classes. Bachelor thesis, Masaryk University, Brno (2013)
3. Doerffel, T.: iTALC Intelligent Teaching And Learning with Computers. User manual (2008)

4. Ternauciuc, A., Ivanc D.: Remote desktop solutions used in e-learning scenarios. In: 6th IEEE International Symposium on Applied Computational Intelligence and Informatics, Timioara, Romania, May 2011
5. Verdon, V.: Manuel d'installation et d'utilisation de Tkontrole 2.1 (2009)
6. http://www.netsupportschool.com/summary.asp
7. Briner, J.V., Roberts, J.E., Worthy, F.: Teaching computer science at a small university. In: The ASCUE Conference, Myrtle Beach, South Carolina, June 2005
8. http://www.faronics.com/fr/products/insight/
9. https://www.lanschool.com/
10. http://www.netop.com/fr/gestion-de-salles-de-classe.htm
11. http://www.realvnc.com/

# Ubiquitous Learning Environments

# Work-in-Progress: Needs and Training in Microelectronics Courses in the MicroElectronics Cloud Alliance

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**Abstract.** The MicroElectronics Cloud Alliance brings together eighteen partners from higher education institutions and enterprises to develop Cloud-based European infrastructure and a new educational system for micro and nanoelectronics, providing a range of open educational resources, remote access and sharing of educational and professional software as well as remote and practice-based learning facilities. The aim of the mClouds project is to define and develop this cloud-based European infrastructure. For this purpose, an analysis of institutions', teachers' and students' needs was carried out in shared IT infrastructure, teaching materials and learning resources, thus meeting the requirements of enterprises in micro- nanoelectronics, and translated into functional specifications of mClouds, obtaining direct information from the users of the courses that allows a feedback and an improvement of the courses.

**Keywords:** Cloud-based e-learning environment · Microelectronics
Open educational resources

## 1 Introduction

As aforementioned, the MicroElectronics Cloud Alliance provides a range of open educational resources (OERs) and virtual or remote access to practice-based learning facilities. In general, no single university is able to afford the necessary infrastructure, clean rooms, technology and experts in all fields of this multidisciplinary science. To share laboratory experiences, CAD tools, project ideas and a common infrastructure, a sort of "educational cloud" over the software/hardware infrastructure can be a solution. All the partners of MECA, HEIs and SMEs, will develop e-learning materials for 22 courses in CAD systems, microelectronics technologies, test, characterization and application of integrated circuits and systems. These 22 new courses foster virtual mobility.


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Each university will allow remote access to its facilities, laboratory experiments or software systems for partners' part of a cloud teaching system, therefore letting them access to new resources.

UNED - as a partner of the project - is developing two MSc courses in Microelectronics as OERs over mClouds architecture, for the rest of partners to access and share them.

## 2 Methodology

This a three-year project, thus planned in order to include the pilot test and the implementation of system for virtual mobility, i.e. the full cycle of design, development, evaluation and implementation. The milestones are:

1. Report on the analysis of needs (5th month),
2. Specification of the three Clouds architectures for open learning resources sharing, IT infrastructure and CAD software common use (end of the 9th month),
3. Job-oriented Job-specific courses and programs on entrepreneurship, project management (15th month),
4. Updated HE curricula in microelectronics in collaboration with the experts from the industry; mClouds system developed and implemented with a minimum of 16 courses delivered as OERs (20th month),
5. Training to all staff involved in the developed OERs,
6. System officers and teachers and trainers from enterprises trained (24th month),
7. Pilot tests (27 month),
8. Exploitation/field trial (36th month).

For defining knowledge, skills and competences needed for the project, we have started with an extensive analysis, i.e. work process analysis in microelectronics and electronics packaging companies.

Specific needs and problems of HE in microelectronics that we intend to solve are:

– Little reference is made to the needs of the workplace; changes in it are not met with changes in education,
– Curricula has to be updated and universities need to collaborate for sharing course materials, intellectual property blocks and ideas.

Therefore, we need a new partnership between education and work to attain synergy between education and industry, to foster the development of competences, technological and entrepreneurial skills.

On the other hand, the emergence of cloud computing is transforming the way organizations and companies purchase and manage computing resources. According to Cruz [1] cloud computing is changing how people carry out personal learning, interactive learning and many-to-many learning, in primary, secondary and higher education. An advantage of cloud computing is the ensured information longevity. Moreover, an important feature is that it allows students to interact and cooperate with an expanding circle of peers, regardless their location.

Following all the above, this proposal is based on the past experiences of almost all HEI partners in the development of e-learning courses and on the expertise of UNED in the development of training courses through remote laboratory access. The focus is on the implementation of an e-learning framework with open educational resources, rooted on the tools developed for cloud management, thus allowing cooperation and distribution of lab sessions, CAD tools and teaching experiences.

## 3 Microelectronics Courses in UNED

UNED developed two different courses: (1) Microelectronics Literacy and Technologies, and (2) Integrated Circuits and Design. These two are part of the 22 courses that all the partners of the project are developing.

The Microelectronics Literacy and Technologies course focuses on delivering basic knowledge in Microelectronics. It is divided into two clearly differentiated blocks: (1) Fundamentals of Microelectronics; and (2) Main Technology Processes in Microelectronics.

The second course (Integrated Circuits and Design) deals with more advanced concepts in Microelectronics. It has been designed to experiment with remote laboratories. UNED has extensive knowledge in remote and virtual tools, given that a distance learning model is its main feature. This course is also divided into two blocks: (1) Technologies of Integrated Circuits; and (2) Design of Digital Integrated Circuits.

Both courses consist of 5 ECTS credits (European Credit Transfer and Accumulation System) and are designed to be carried out on several phases. VISIR (Virtual Instruments System in Reality) is the tool used in these courses. It is a remote lab for electric and electronic circuits' experiments, developed at Blekinge Institute of Technology (BTH), Sweden, and used in several universities worldwide [2].

The VISIR software is released under a GNU GPL license. "Web Interface" is the website of VISIR. When a client logs in, it generates a session cookie stored in the "Measurement Server" for authentication. The "Experiment Client" accesses through the Web Interface, it being the entire laboratory workbench through an HTML page as an embedded object. The roles of the Measurement Server are: authentication at each request of the session cookie; validation of the construction of the circuit and instrument values (defined previously by the administrator/teacher); handling of time-sharing between simultaneous users; handling of requests queue. The "Equipment Server" is a stand-alone equipment controller written in LabVIEW, which handles all the instrument hardware together with the relay switching matrix.

## 4 Future Outcomes

First steps in the deployment of this model have already been taken. All HEIs have installed their own CloudStack software [3], virtual machines (VMs) for end-user self-service. The starting point is connecting the different institutions and placing a CloudStack controller in one of our partners. The next step is deploying a Moodle web platform in each partner. Along with Moodle, all CAD software and remote laboratories will be implemented, being a challenge to find a solution to the issue of sharing software or hardware licenses between institutions.

## 5 Conclusions

The deployment of an educational cloud will allow virtual mobility of students and an easy update of contents. Moreover, involving employers and labor market institutions will help attune curricula to current and emerging labor market needs as well as fostering employability and entrepreneurship.

The mCloudsarchitecture will enable the distribution of resources throughout Europe. Thus, instructors from different European countries can take advantage of using a running lab-experiment and delivering it in their native language.

The purpose of this Erasmus+ Knowledge Alliance project is to build a long-lasting partnership of SMEs with HEIs, which could evolve in joint research activities. Double-line feedback, knowledge and synergy will be gained because of the enterprise/HEI partnership, improving research and innovation on companies due to HEI academic competitive view, thus ameliorating HE as a result of applying companies' industrial application experience and expertise.

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## References

1. Cruz, L.: How Cloud Computing is Revolutionizing Education. Cisco's Technology News Site (2012)
2. Gustavsson, I., Nilsson, K., Zackrisson, J., Garcia-Zubia, J., Hernandez-Jayo, U., Nafalski, A., Nedic, Z., Gol, O., Machotka, J., Pettersson, M.I., Lago, T., Hakansson, L.: On objectives of instructional laboratories, individual assessment, and use of collaborative remote laboratories. IEEE Trans. Learn. Technol. **2**(4), 263–274 (2009)
3. OpenStack. http://www.openstack.org/. Accessed Sept 2016

# A Proposed Lightweight Cloud Security Framework to Secure Communications Between Internet of Things Devices

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**Abstract.** Cloud services can be categorized into Infrastructure as a Service (IaaS), the Platform as a Service (PaaS) and the Software as a Service (SaaS). In (Iaas), the whole IT infrastructure can be delivered as a service. In (Paas), a virtual platform over the internet gives users the ability to develop and deploy applications. In (SaaS), it provides accessing an application through the internet on demand. In the (SaaS) layer, a single instance on the cloud for multiple users could be provided. Google Apps, one of the most powerful (SaaS) that is used by many institutes to provide a variety of Web-based applications for business, education, and government. Security in Cloud computing is an important and critical problem. Cloud service provider and the cloud service consumer should make sure that the cloud is safe enough from all the external threats so that the customer does not face any problem such as loss of data or data theft. Internets of Things (IoT) are small IP enabled devices that can cooperate to perform specific functions for various set of applications. This new emerging technology is strongly involved in applications that have direct impact on human welfare, such as business, education and government. Securing IoT device's communications are becoming a must. In this paper a lightweight technique for secure and authentic communication between IoT devices. That lightweight technique is based on framework of ideas from virtual server, network management and cloud services.

**Keywords:** Cloud computing · Data security · Cloud issues · Data issues
Security issues · IoT security · Network management · Light weight protocols
Virtual server


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## 1 Introduction to Cloud Computing Security

Cloud computing and Internet of Things (IoT) are two recent technologies which are used together in many applications. IoT mainly contains a large number of heterogeneous physical and virtual objects. Cloud computing paradigm [3] realizes and promotes the delivery of hardware and software resources over the Internet and according to an on-demand utility based model. Depending on the type of computing resources delivered via the cloud, cloud services take different forms such as Network as a Service (NaaS), Infrastructure as a service (IaaS), Platform as a service (PaaS), Software as a service (SaaS), Storage as a service (STaaS) and more. These services hold to promise to deliver increased reliability, security, high availability and improved QoS at an overall lower Total Cost of Ownership (TCO).

Machine to machine (M2M) communication protocols are main participant of IoT applications. They are concerned with communication between large numbers of heterogeneous geographically distributed "things". These protocols need to handle large number of sensors. Cloud infrastructures could enhance the computational capacities of IoT applications, given that several multisensory applications need to perform complex processing that is subject to timing and QoS constraints. Also, several IoT services could benefit from a utility-based delivery paradigm, which emphasizes the on-demand establishment and delivery of IoT applications over a cloud-based infrastructure [3]. Sensor-Clouds Project [4, 5], blends sensors into the data center of the cloud and accordingly provide service oriented access to sensor data and resources. Several recent research initiatives are focusing on real-life implementation of sensor clouds [5].

In [6] as means of benefitting from the cloud's storage capacity and application hosting capabilities the FP7 Smart Santander project is introduced. In [7] proposes an implementation and design of a cloud-based monitoring system with wireless network and an Internet of Thing (IoT) platform in order to real-time delivery of the field measured information to the user.

Finally, authors had proposed several ideas on e-learning, m-learning and cloud computing in e-learning process [14–20].

## 2 Essential Characteristics of Cloud Computing

1. On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider [21].
2. Broad network access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations) [21].
3. Resource pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to

specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth [21].

4. Rapid elasticity: Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time [21].
5. Measured service: Cloud systems automatically control and optimize resource use by leveraging a metering capability (this is done on a pay-per-use or charge-per-use basis) at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service [21].

## 3 Advantages and Disadvantages of Cloud Computing

Cloud computing has great benefits for the public sector and government IT organizations that want to take advantage of it, and in brief, they are as follows [22–25]:

1. Location and device independence: Users are not tied to any device or location to access the service. All they need is a simple Internet connection and a web browser.
2. Reduced cost: Cloud technology is paid incrementally based upon, consumption, this means saving the organization money.
3. Increased storage: Organizations may store more data in the cloud than on a private computer or network system.
4. Highly automated: Cloud computing services are highly automated. This is based upon all efforts for maintenance and related issues that are made by the cloud service provider.
5. Flexibility and scalability: A change of resources in any way is possible and easy to implement mush faster than in past computing methods. IT departments that anticipate an enormous increase in user load does not need to scramble to secure additional hardware and software with cloud computing. Instead, an organization may add and subtract capacity as dictated by its network load. Better still, because cloud-computing follows a utility model in which service costs are based upon consumption, companies will only pay for what they use.
6. IT focus shift: No longer having to worry about constant server updates and other computing issues, IT will be free to concentrate on innovation.
7. Utilization and efficiency improvement: Based upon the cloud service provider, efficiency will be improved greatly, much more than it could possibly for a local IT team.
8. Easy implementation: Without the need to purchase hardware, software licenses or implementation services, a company may get its cloud computing arrangement off the ground in record time and for a fraction of the cost of an on premise solution.
9. Skilled practitioners: When a particular technology becomes popular, it is not uncommon for a whole slew of vendors to jump on the bandwagon. In the case of

cloud computing, however, vendors have typically have been reputable enough to offer customers reliable service and large enough to deliver huge datacenters with endless amounts of storage and computing capacity. These vendors include industry stalwarts such as Microsoft, Google, IBM, Yahoo, and Amazon.

10. Quality of service: Network outages may send an IT department scrambling for answers. Yet, in the case of cloud computing, it is up to a company's selected vendor to offer 24/7 customer support and an immediate response to emergency situations. That is not to suggest that outages do not occur. In February 2008, Amazon's S3 cloud-computing service experienced a brief outage that affected a number of companies. Fortunately, service was restored within three hours.

11 Greener technology: A typical data center consumes up to 100 times more power than an equivalent sized office building. The carbon footprint of a typical data center is therefore a significant concern for many organizations that could be improved by adopting the cloud technology.

On the other hand, cloud computing has its own disadvantages that usually vary from provider to provider and are very much dependent upon the service provider policies. The disadvantages are summarized as [22–25]:

1. Customer control: The customer does not have control over the cloud provider's server, software, and security processes.
2. Data security: The customer's data is under the provider's control, so this requires strong trust between two parties, something that is usually very difficult to obtain.
3. Anchoring problem: It is almost impossible to migrate massive amounts of data from the service provider to any other party in the event of any need to change the provider, so the customers are almost anchored to their initial provider.
4. Hidden costs: In some cases, hidden costs such as additional cost of data transfer are applied.
5. Network dependability: If the network crashes, the customer will be unable to use the services until the network is restored and it is backed up.
6. Legacy compatibility: Some applications or hardware might require having a hard drive attached to the computer; these might be hard to get working properly with the hard drive on a remote server.
7. Security: In nearly every survey done about cloud computing the top reason given for not adopting it is a concern over security.

## 4 Securing IOT Devices

The process of securing IoT devices must cover three main services [1]:

1. Authentication, It is dangerous to accept data from either unverified devices or unverified users so authentication is an essential part in controlling IoT devices.
2. Encryption, Encryption is used to confirm confidentiality and integrity of messages or communication between either IoT devices or user to IoT device communication.
3. Key management, Key management is the process of exchanging cryptographic key securely for further authentication or encryption.

OAUTH 2.0 [2] is an open authorization protocol which enables applications to access each other's data. Also it enables a third-party application to obtain limited access to an HTTP service, either on behalf of a resource owner by orchestrating an approval interaction between the resource owner and the HTTP service, or by allowing the third-party application to obtain access on its own behalf. OAUTH 2.0 has many advantages such as simplicity, security, privacy and networking. The main disadvantages of this protocol are Lack of anonymity, Lack of market saturation, phishing great effect and bad precedents. Recent research on IoT security introduces the OpenID Connect certification. The OpenID Connect is built on OAuth 2.0 It provides support for federated login and the ability to convey authentication information.

At [12] the authors mentioned an efficient key management for IOT owner in the cloud [13], they present a security a minimal cost for the client model without encryption and an access control model to minimize the key management cost for IOT owner. Also they provide an update authorization method to minimize the cost dynamically.

## 5 The Proposed Framework

### 5.1 The Goal of the Paper

In this paper a generalized framework for securing IoT devices and their communications is introduced. This framework utilizes ideas from network management, virtual server, lightweight protocols, and cloud services to perform authentication, encryption and key management.

Lightweight protocol, i.e. 6LoWPAN [8], LTE MTC [9], refers to any protocol that has a lesser and leaner payload when being used and transmitted over a network connection. It is simpler, faster and easier to manage than other communication protocols used on a local or wide area network.

A reserved cloud resources are used to run a virtual server managed only via specific authenticated user which is allowed to perform specific functions on a set of IoT devices. That virtual server is used by one user the same way manager/agent is relating to each other in network management framework. Client/server based systems imply that a small number of servers must service a large number of clients, in network management the situation is reversed, large numbers of servers (agents) serve a small number of clients (managers) [10]. The lightweight virtual server will be controlled by one user, and controlling all other IoT devices in order to perform the three security services mentioned before.

The utilization of cloud and the virtual server provides powerful, secure and authentic IoT devices with little or no probability for being compromising plus budget economy that cloud provided.

Utilizing cloud provides double security layer for securing IoT devices and user. IoT user can reserve specific resources on a cloud to run a virtual server for monitoring IoT devices and protecting credentials used for logging into these devices. Making use of the security provided by the cloud and the security provided by the virtual server (authentication/authorization) makes the IoT devices more secure and less vulnerable to attacks.

Based on the IoT background and security issues discussed earlier, the goal of this paper is to develop a lightweight authentication framework between devices and keep communication between them secured, such that:

1. In case of authentication: In case of identification, any device can claim to be another device and take lot of privileges based on the new clamed role. In IoT, devices have not a limited number; in this case a lightweight authentication technique is required. Devices which perform critical roles either to other devices or users must authenticate themselves prior to further interactions.
2. In case of encryption: Communication between "things" must be secured against various attacks such as Man in Middle (MiM) attack [11]. Securing communication between devices must also guarantee the integrity and confidentiality of messages.
3. In case of key management: Encryption and decryption are performed by cryptographic keys. In symmetric encryption the single key is used by both the sender and the receiver. The key is generated in one side and must be transferred securely to the other side. Key management is concerned with the methods adopted to exchange the keys securely. PKI [11] is a common framework that uses asymmetric cryptography [11] to exchange symmetric keys.

## 5.2 The Proposed Framework

The proposed framework utilizes ideas from network management. In the area of network management, large numbers of heterogeneous network elements or agents are managed by a small set of managers [10]. Network Management communications are inherently asymmetrical [10] as the requester and the responder are not peers and have dissimilar functions. In this case the manager is not the same as the Agent in terms of functionality. Figures 1 and 2 illustrates the differences between Client/Server and Manager/Agent communication. A managing application plays the role of a manager in charge of the management, and the network element plays the role of the agent that supports the manager by responding to its requests and notifying it proactively of unexpected events.

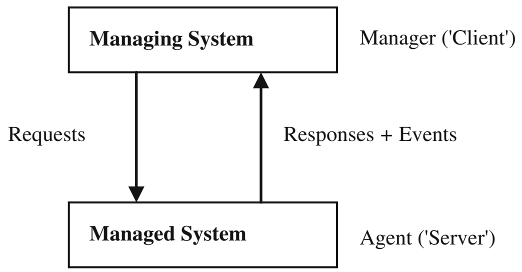


**Fig. 1.** Manager/Agent communication [10]

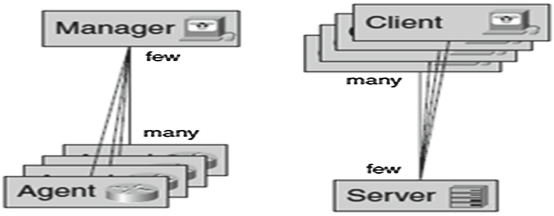


**Fig. 2.** Manager/Agent versus Client/Server [10]

The proposed framework components act together the same way as in network management. The user can only access a program runs on cloud. We will refer to this program as virtual lightweight server. This virtual lightweight server takes the role of Manager which manages many IoT devices and can only be accessed via a one specific user as shown in Fig. 3.

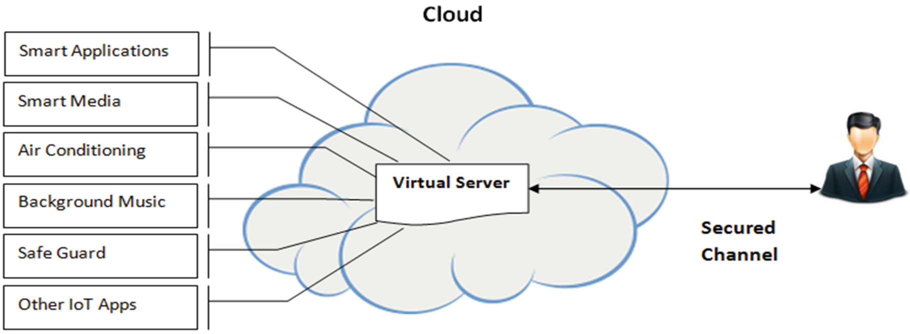


**Fig. 3.** The proposed framework components

To the best knowledge of the authors, no previous researches utilize ideas from cloud, virtual server, security and network management the same way as the paper did.

The Roles of the Virtual lightweight server is:

1. Enforcing the three security issues (authentication, encryption and key management).
2. Providing single access point for all IoT devices belonging to single user.

The proposed framework advantages over other frameworks:

1. The usage of cloud provides powerful low cost framework.
2. Provides double security layer the security of cloud and the virtual lightweight server.
3. Simple, cheap, fast and easy to deploy.

## 6 Conclusion and Further Work

The paper proposes a lightweight security framework based on a virtual server deployed in the cloud to securely manage and control the devices of Internet of Things, where users interact with IoT devices through the virtual server. The framework uses ideas from network management for securing Iot objects and their communication.

The proposed framework is still in the idea stage, no technical details were given on how the server will be deployed, how security credentials are distributed between users, server and IoT devices, How control access could be achieved and where, is the proposed solution target to single point of failure? do we have an end-to-end security or instead two segments of a pseudo point to point security.

It remains to implement and test the framework in order to evidently persuading vendors and researchers adopting the paper's framework. That will be the sequel paper main effort.

## References


1. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of Things (IoT): a vision, architectural elements, and future directions. Future Gener. Comput. Syst. **29**(7), 1645–1660 (2013). Elsevier Science, Amsterdam, The Netherlands. ISSN: 0167-739X
2. IETF RFC 6749. https://tools.ietf.org/html/rfc6749
3. Suciu, G., Suciu, V., Martin, A.: Data, Internet of Things and cloud convergence—an architecture for secure e-health applications. J. Med. Syst. **39**(11), 141 (2015)
4. Hassan, M.M., Song, B.,Huh E.N.: A framework of sensor cloud integration opportunities and challenges. In: Proceedings of International Conference Ubiquitous Information Management Communication, pp. 618–626 (2009)
5. Fox, G.C., Kamburugamuve, S., Hartman, R.D.: Architecture and measured characteristics of a cloud based internet of things. In: International Conference on IEEE Collaboration Technologies and Systems (CTS), pp. 6–12 (2012)
6. Jara, A.J., Genoud, D., Bocchi, Y.: Sensors data fusion for smart cities with KNIME - a real experience in the Smart Santander Test bed. In: I.E. World Forum on Internet of Things (WF-IoT), pp. 173–174 (2014)
7. Kim, B., Jung, C.: Design and implementation of cloud based realtime temperature and humidity monitoring system of honey bee colony. J. Apiculture **30**(4), 263–267 (2015)
8. Kushalnagar, N., Montenegro, G., Schumacher, C.: IPv6 over LowPower Wireless Personal Area Networks (6LoWPANs): Overview, assumptions, problem statement, and goals. Internet Engineering Task Force (IETF), Fremont, CA, USA, RFC4919, vol. 10 (2007)
9. Hasan, M., Hossain, E., Niyato, D.: Random access for machine-to-machine communication in LTE-Advanced networks: Issues and approaches. IEEE Commun. Mag. **51**(6), 86–93 (2013)
10. Clemm, A.: Network Management Fundamentals (2007). ISBN-10: 1587201372, ISBN-13: 978-1587201370
11. Stamp, M.: Information Security: Principles and Practice, 2nd edn. Wiley, San Jose (2011). https://doi.org/10.1002/9781118027974
12. Motawie, R., El-Khouly, M.M., El-Seoud, M.S.A.: Security Problems in Cloud Computing (2016). https://doi.org/10.3991/ijes.v4i4.6538

13. Leandro, M.A.P., Nascimento, T.J., dos Santos, D.R., Westphall, C.M., Westphall, C.B.: Multitenancy authorization system with federated identity for cloud-based environments using shibboleth. In: Proceedings of the Eleventh International Conference on Networks, pp. 88–93 (2012)
14. El-Sofany, H.F., Al Tayeb, A., Alghatani, K., El-Seoud, S.A.: The Impact of cloud computing technologies in e-learning. Int. J. Emerg. Technol. Learn. **8**(1), 37–43 (2013). ICL2012
15. El-Seoud, M.S., El-Sofany, H.F., Taj-Eddin, I.A.T.F., Nosseir, A.F., El-Khouly, M.M.: Implementation of web-based education in Egypt through cloud computing technologies and its effectbon higher education. High. Educ. Stud. **3**(3), 62 (2013)
16. El-Seoud, M.S.A., Taj-Eddin, I.A.T.F.: Developing an android mobile bluetooth chat messenger as an interactive and collaborative learning aid. In: Auer M., Guralnick D., Uhomoibhi J. (eds) Interactive Collaborative Learning, ICL 2016. Intelligent Systems and Computing, vol 545, pp. 3–15. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-50340-0_1. http://www.icl-conference.org/icl2016/
17. El-Seoud, M.S.A., Taj-Eddin, I.A.T.F.: Beyond android: an essential integration for better utilization In: International Conference on Interactive Mobile Communication Technologies and Learning (IMCL2016), pp. 98–102. IEEE (2016). https://doi.org/10.1109/IMCTL.2016.7753780. http://www.imcl-conference.org/imcl2016/
18. El-Seoud, M.S.A., El-Sofany, H.F., Taj-Eddin, I.A.T.F.: Mobile applications and semantic-web a case study on automated course management. Int. J. Interact. Mob. Technol. (iJIM) **10**(3), 42–53 (2016). https://doi.org/10.3991/ijim.v10i3.5770. International Association of Online Engineering. http://online-journals.org/index.php
19. El-Seoud, M.S.A., El-Khouly, M., Taj-Eddin, I.A.T.F.: Strategies to enhance learner's motivation in e-learning environment. In: Proceedings of 18th International Conference on Interactive Collaborative Learning (ICL2015), pp. 944–949. IEEE (2015). https://doi.org/10.1109/ICL.2015.7318154. http://www.icl-conference.org/icl2015/. ISBN: 978-1-4799-8706-1/15 ©2015
20. El-Seoud, M.S.A., El-Sofany, H.F., Karkar, A., Dandashi, A., Taj-Eddin, I.A.T.F., AL-Ja'am, J.M.: Semantic-web automated course management and evaluation system using mobile applications. In: Proceedings of 18th International Conference on Interactive Collaborative Learning (ICL2015), pp. 271–282. IEEE (2015). https://doi.org/10.1109/ICL.2015.7318037. http://www.icl-conference.org/icl2015/. ISBN: 978-1-4799-8706-1/15 ©2015
21. NIST: National Institute of Standards and Technology - Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director. NIST Cloud Computing Standards Roadmap Working Group, NIST Cloud Computing Program, Information Technology Laboratory, NIST Special Publication 500-291, Version 2, July 2013. http://dx.doi.org/:10.6028/NIST.SP.500-291r2
22. OrBytes Website Admin: Cloud Computing (2009). http://www.orbytesolutions.com/services/index.php?option=com_content&view=article&id=55&Itemid=40. Accessed 8 Nov 2010
23. Waxer, B.: The Benefits of Cloud Computing (2009). http://www.webhostingunleashed.com/features/cloud-computing-benefits/. Accessed 21 Dec 2010
24. Dans, E.: Benefits and Disadvantages of Cloud Computing (2011). http://algramrandomramblings.blogspot.com/2011/01/benefits-and-disadvantages-ofcloud.html. Accessed 14 Mar 2011
25. Kynetix Technology group. Cloud Computing Strategy Guide (2009). https://sites.google.com/site/cloudmanual/success-factors. Accessed 2 Dec 2010

# Comparable and Analytical Study Between Some Security Issues in Cloud Computing

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**Abstract.** Cloud Computing appears as a computational model and a distributive architecture framework. The main objectives of cloud computing are to provide secure, quick, convenient data storage and net computing service, with all computing resources visualized as services and delivered over the Internet. The term "Cloud Computing" has been in the spotlights of IT, CS and CE specialists in the last years because of its potential to transform this industry. Security in Cloud Computing is an important and critical aspect, and has numerous issues and problem related to it. Cloud service provider and the cloud service consumer should make sure that the cloud is safe enough from all the external threats so that the customer does not face any problem such as loss of data or data theft. This research presents and classifies the factors that affect the security of the cloud then it explores the cloud security issues and problems faced by cloud service provider and cloud service consumer. The main goal of this research study is to introduce a comparable analysis for the proposed security issues, the security categories, and the cloud computing services.

**Keywords:** Cloud computing · Cloud computing security · Security issues
Cloud issues

## 1 Introduction

The main idea of cloud computing is to deliver both software and hardware as services. Basically there are three main layers of services over the cloud that are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [26]. Individuals and organizations have been considering services over the cloud to cut the costs of expenditure, without any compensation in utilizing recent technologies [27]. A survey conducted by IDC [28] shows the importance of the challenges for those considering cloud computing as an option. It is shown in Fig. 1, that security is the utmost concern. Moving essential data over a network to a third-party resource is not an


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easy decision to be approved. There should be many guarantees as good performance, availability, and mostly secure transmission and storage. On the other hand, organizations are more reluctant to move important data when the actual infrastructure, precise cost estimation, security level, privacy level, trust, and many other concerns will be unknown.

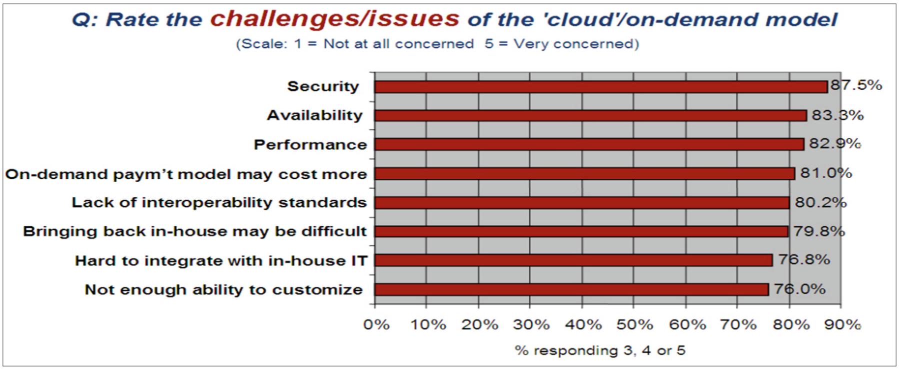


**Fig. 1** Challenges in considering cloud computing [3, 4]

Authors realized the importance of cloud computing in education; they had proposed several ideas on e-learning, m-learning and cloud computing in e-learning process [37–43].

The paper is organized as follows: in section two, we present an overview about cloud computing basic concepts. In section three, we present a brief introduction for cloud computing security, and introduce the main categories of security issues around cloud computing. In section four we introduce a comparable analysis for the proposed security issues, the security categories, and the cloud computing services. The paper finally concluded in section five.

## 2 Cloud Computing Basic Concepts

Cloud computing is considered as the 5th generation of architecture in the IT world. It follows up the following architectures in the chronological order of their appearance: Mainframes (1970), Client-server (1980), Web (1990), SOA (2000) and Cloud (2010). It is a new model for hosting resources and provisioning of services to the consumers [1]. It provides a convenient, on-demand access to a centralized shared pool of computing resources that can be deployed by a minimal management overhead and with a great efficiency. Cloud Computing *providers* depend on the Internet as the intermediary communications medium leveraged to deliver their IT resources to their *consumers* on a pay-as-you-go basis. By using cloud computing, consumers can be access resources directly through the internet from anywhere by using any internet devices, and at any time without any technical or physical concerns [1]. In the literature, there are several definitions of the cloud computing. However, the definition given by the NIST "*National Institute of Standards and Technology*" is an authoritative one. NIST defines; Cloud Computing as: "*Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*" [2]. This cloud model is composed of five essential characteristics, three service models, and four deployment models, as shown in Fig. 2 [2, 3].

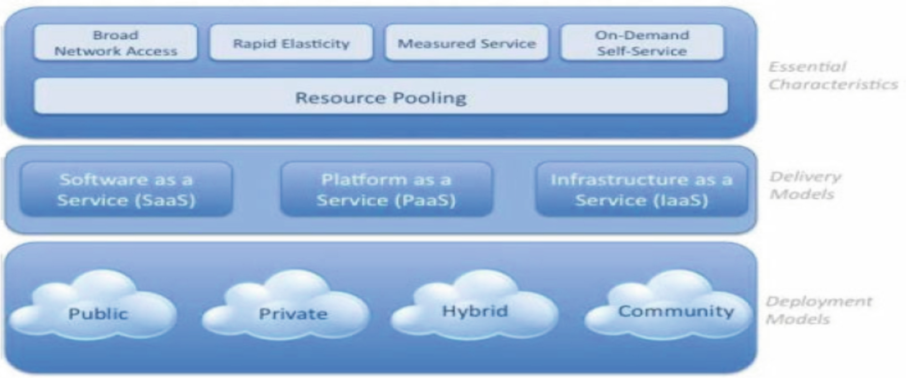


**Fig. 2** NIST visual model of cloud computing definition

### 2.1 Essential Characteristics of Cloud Computing [2]

1. On-demand self-service
2. Broad network access
3. Resource pooling
4. Rapid elasticity
5. Measured service

### 2.2 Service Models of Cloud Computing

1. Software as a Service (SaaS): The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure (i.e., the collection of hardware and software). The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings [1]. Examples of SaaS offerings include: Google Apps [5]. Microsoft Office 365 [6]. NetSuite [7]. Salesforce [8]. SurveyTool [9]. Zoho [10]. Rackspace.com [4].

2. Platform as a Service (PaaS): The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment [1, 2]. Examples of PaaS offerings include: CloudBees [11]. Engine Yard [12]. Google App Engine [13]. Heroku [14]. Microsoft Windows Azure [15]. Salesforce Force.com [16].
3. Infrastructure as a Service (IaaS): The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls) [1, 2]. Examples of IaaS offerings include: Amazon Elastic Compute Cloud (EC2) [17]. Amazon Simple Storage Solution (S3) [18]. GoGrid Cloud Servers [19]. Rackspace Cloud Servers [20].
4. Other Service Models of Cloud Computing: There are actually more service models than the three (IaaS, PaaS, SaaS) widely in use today. Service model like Database as a Service (DaaS) is emerging as useful model. How one Selects the appropriate service model depends on factors such as availability of suitable application software Need for development and test environment, need for effective computing infrastructure control and management required distribution of data, services, and infrastructure, existence and complexity of enterprise IT infrastructure and datacenter/warehouse. We can denote the other service categories which are more commonly classified as anything as a Service by XAAS, where X is the name of the service category. In addition to the NIST definition, we can find other service models [21].

### 2.3 Deployment Models of Cloud Computing

The basic types of Clouds in Cloud Computing include [2]:

1. Private cloud
2. Community cloud
3. Public cloud
4. Hybrid cloud

### 2.4 Advantages and Disadvantages of Cloud Computing

Cloud computing has great benefits for the public sector and government IT organizations that want to take advantage of it, and in brief, they are as follows [22–25]:

1. Location and device independence
2. Reduced cost
3. Increased storage

4. Highly automated
5. Flexibility and scalability
6. IT focus shift
7. Utilization and efficiency improvement
8. Easy implementation
9. Skilled practitioners
10. Quality of service
11. Greener technology

On the other hand, cloud computing has its own disadvantages that usually vary from provider to provider and are very much dependent upon the service provider policies. The disadvantages are summarized as [22–25]:

1. Customer control
2. Data security
3. Anchoring problem
4. Hidden costs
5. Network dependability
6. Legacy compatibility
7. Security

## 3 Cloud Computing Security

Security is consistently one of the top concerns, specifically the security related to technology, data and information. Security concerns arise because both the customer data and program reside within the providers premises. Companies need to be realistic about the level of security they may achieve inside of their own business, and how that might compare to cloud provider. It is well known that more than 70% of intellectual property breaches are a result of attacks made from within the organization. Despite this, security will be raised as a concern regarding cloud computing for many years to come. There is still much work to be done before more formalized standards are set in place. Organizations such as the Cloud Security Alliance are at the forefront of addressing these issues. Figure 1 shows that about 88.5% of the customers that are likely to avoid using cloud computing cite security as the main reason for this denial. *Security* is a cross-cutting function that spans all layers of the *reference architecture* as shown at The Combined Conceptual Reference Diagram at [2]. The Combined Conceptual Reference Diagram, involving end-to-end security that ranges from *physical security* to *application security*, and in general, the responsibility is shared between *cloud provider* and *cloud consumer*. For *example*, the protection of the physical resource layer requires physical security that denies *unauthorized access* to the building, facility, resource, or stored information. *Cloud Providers* should ensure that the facility hosting cloud services is secure and that the staff has proper background checks. When data or applications are moved to a cloud, *Cloud Consumers* ensure that the cloud offering satisfies the security requirements and enforces the compliance rules. It is also important to note that *security*, *compliance*, and *policy requirements* are a function of the legal jurisdiction of the country in which the cloud services are provided and can vary from country to country. An independent *audit* should be conducted to verify the compliance with regulations or security policies.

*Security* is simply defined as *"saving data and program from danger and vulnerability"*. Dangers that threaten the data include: disruption of services, theft of information, loss of privacy, and damage of information. While the most crucial vulnerabilities include: hostile program, hostile people giving instructions to good programs, and "Bad guys" who corrupting or eavesdropping on communications.

We divide the common *security issues* around cloud computing across five main categories:

1. **Access Control Security**: covers authentication and access control issues. It also covers issues that affect privacy of user information and data storage. It is a user-oriented category and includes *identification*, *authentication* and *authorization* issues.
2. **Cloud Infrastructure Security**: covers security issues and attacks that are specific to the cloud infrastructure (IaaS, PaaS and SaaS) such tampered binaries and privileged insiders, and is particularly related with virtualization environment.
3. **Data Security**: covers data related security issues including *data migration*, *integrity*, *confidentiality*, and *data warehousing*.
4. **Network Security**: refers to the medium through which the users connect to cloud infrastructure to perform the desired computations. It includes browsers, network connections and information exchange through registration. Covers network related security issues including: *network attacks* such as *connection availability*, *denial of Service*, *flooding attack*, *internet protocol vulnerabilities*, *etc*.
5. **Security Standards**: deals with regulatory authorities and governing bodies that define cloud security policies to ensure secure working environment over the clouds. It governs the policies of cloud computing for security without compromising reliability and performance. It includes *service level agreements*, *auditing* and other *agreements among users*, *service provider* and *other stakeholders*.

## 4 Analysis of Security Issues in Cloud Computing

There are some special issues that acting as a fence in the trust and adoption of using cloud computing. In this section we introduce the relationship between the proposed issues and the security categories mentioned in the last section as well as the mapping between them and the cloud computing services presented in Sect. 2 (Table 1).

**Table 1.** Security issues, Security categories and Cloud Computing Services Mapping

| # | Issues | Description | Security categories | Cloud computing services |
|---|---|---|---|---|
| 1 | Abstraction | Cloud service provider provides abstraction by hiding the complexities in its infrastructure and platform. Users have no knowledge about the storage of its data. In other words issue of transparency rising in user mind [29]. Thus in event of security breach, it becomes difficult for a user to isolate a particular physical resource that has a threat or has been compromised | - Access Control Security<br>- Cloud Infrastructure Security<br>- Network Security | IaaS,<br>HaaS<br>CAAS<br>NAAS<br>SAAS |
| 2 | Accessibility | Cloud computing offers many benefits in terms of low cost and *accessibility* of data. Accessibility is relevant to cloud computing services at the application level where a human interacts with an application. This is where accessibility is measured. Therefore, many of the existing accessibility standards for ICT applications are relevant to cloud computing applications [2]. In SaaS model, users accessing different application from different locations using public and private networks. This diversity imposes severe security concerns. One of the main concerns is to provide accurate and uninterruptable access to the cloud resources [30] | - Access Control Security<br>- Data Security<br>- Network Security | SaaS,<br>DaaS<br>NAAS<br>MAAS |
| 3 | Application security | Application level security relates the use of different resources so that it can offer security to applications in a manner so that unauthorized users cannot access the network services. In cloud computing normally security measures are taken at network and transport layer of the OSI model. It is necessary to use tools and technologies to implement the security at the application layer. There are a number of factors involved in the security of | - Access Control Security<br>- Data Security<br>- Network Security | SaaS,<br>PaaS,<br>IaaS<br>DaaS<br>NAAS |

(*continued*)

**Table 1.** (*continued*)

| # | Issues | Description | Security categories | Cloud computing services |
|---|---|---|---|---|
| | | applications. The first point is the coding of application, then the server or hardware that is used to run application, and network through which it is accessed. The ten most important threats are highlighted by Open Web Application Security Project -OWASP [30, 31] | | |
| 4 | Audit and compliance | Data format standards for auditing, compliance data and metadata are needed. In addition, policy, process and technical control standards are needed to support more manageable assessment and accreditation processes, which are often a prerequisite before a system is put in operation [2] | - Access Control Security<br>- Data Security<br>-Network Security<br>- Security Standards | SaaS, PaaS, IaaS |
| 5 | Cloud standards | *Standards* continue to rapidly evolve in step with technology. Hence, *cloud standards* may be at different stages of maturity and levels of acceptance [2]. Standards with common interest are necessary to get the interoperability among clouds. Data lock-in and Vendor Lock-in issues occurs due to lack of standards [32] | - Access Control Security<br>- Cloud Infrastructure Security<br>- Data Security<br>- Security Standards | SaaS, PaaS, IaaS |
| 6 | Data privacy | A cloud provider's data center lies in one country and the customer using the service from another country, in this case customer's data is owned and under the control of service provider, customer has no direct control over his data [1] | - Access Control Security<br>- Data Security<br>- Network Security | SaaS, IaaS DaaS |
| 7 | Data transmission | Security of data during transmission is another alarming challenge. Strong encryption and decryption techniques are necessary to exchange the data between service provider and customer. Necessary tools and technologies should be implemented to provide the confidentiality and | - Access Control Security<br>- Data Security<br>- Network Security | SaaS, IaaS DaaS, SAAS |

(*continued*)

**Table 1.** (*continued*)

| # | Issues | Description | Security categories | Cloud computing services |
|---|---|---|---|---|
| | | integrity of data during transmission [36] | | |
| 8 | Data protection | Multiple users from different sites sharing the cloud computing infrastructure at the same time, hence data of each user is stored and processed in shared environment. Any malicious entity may temper the data [1] | - Access Control Security<br>- Data Security<br>- Network Security | SaaS, IaaS DaaS |
| 9 | Data Security | Data security and protection can be analyzed using a data life cycle | -Access Control Security<br>- Data Security<br>- Network Security | SaaS, IaaS DaaS |
| 10 | Identity management | Many of the threats that cloud *providers* and *consumers* face can be dealt with through traditional security processes and mechanisms such identity management. However, *risk management* activities must be undertaken to determine how to mitigate the threats specific to different cloud models and to analyze existing standards for gaps that need to be addressed [2]. On the other hands, to access the cloud computing each user is assigned identity to access the cloud computing services and applications. Any malicious entity may impersonate a legitimate user and access a cloud resources leading to unavailability of a service for actual user. Also user may cross its rights while accessing cloud computing. In other words authentication and authorization issues should be resolved | - Access Control Security<br>- Cloud Infrastructure Security<br>-Network Security<br>- Security Standards | SaaS, PaaS, IaaS, DaaS HaaS, CAAS NAAS MAAS |
| 11 | Lock-in | Lock-in may be classified as data lock-in and vendor lock-in. Data lock-in occurs when a user wants to jump to another cloud provider but | -Access Control Security | SaaS, PaaS, IaaS, |

(*continued*)

**Table 1.** (*continued*)

| # | Issues | Description | Security categories | Cloud computing services |
|---|---|---|---|---|
| | | due to the lack of standardized API he cannot took his data back. Vendor lock-in is a situation in which a customer using a service cannot easily transition to a competitor's service [33, 34] | - Data Security<br>- Network Security | |
| 12 | Multi-tenancy issue | In multi-tenancy environment a single instance of software serves multiple tenants. It is difficult to protect user's data from unauthorized users accessing the same physical server. In multi-tendency architecture, multiple users from different sites will access the cloud services. It will create a network congestion problem. This issue will resolve by bifurcating different services in to layered approach [34] | - Access Control Security<br>- Cloud Infrastructure Security<br>-Network Security<br>- Security Standards | SaaS,<br>IaaS<br>DaaS<br>HaaS |
| 13 | Network Security | In cloud computing multiple users accessing different services and applications from remote locations. Attacks like wiretapping, denial of service, masquerading, disruption of service, modification of a message will definitely effect the security of cloud computing. This issue will resolve by implement firewall and Virtual Private Network (VPN) to access secure data from cloud so that our cloud user access data trustworthy [35] | - Access Control Security<br>- Cloud Infrastructure Security<br>- Data Security<br>-Network Security | SaaS,<br>IaaS<br>DaaS<br>CAAS<br>NAAS<br>MAAS |
| 14 | Service agreement | At the moment, most cloud service agreements are expressed in human-readable terms for review by legal staff and management. Tools are increasingly available, however, for expression of service agreement conditions, remedies, and provisions that can be expressed in machine-readable terms and that can even serve as the basis for service templates that can be provisioned automatically, directly from the | - Access Control Security<br>- Cloud Infrastructure Security<br>- Data Security<br>-Network Security<br>- Security Standards | SaaS,<br>PaaS,<br>IaaS |

(*continued*)

**Table 1.** (*continued*)

| # | Issues | Description | Security categories | Cloud computing services |
|---|---|---|---|---|
| | | service agreement template [2]. A service agreement is a document that describes the relationship between the service provider and customer. It highlights the customer requirements, simplifies difficult issues, and provides a framework for understanding | | |
| 15 | Virtualization | Hypervisor is the main target of hackers. The usage of storage and memory, and allocation and de-allocation of resources over a public cloud are another security concern related with VMs [35]. Also weak hypervisor may also be affected by different attacks | - Access Control Security<br>- Cloud Infrastructure Security<br>- Data Security<br>-Network Security | SaaS,<br>PaaS,<br>IaaS<br>DaaS<br>SAAS<br>MAAS |

## 5 Conclusions

There are numerous security issues for cloud computing as it encompasses many technologies including networks, databases, operating systems, virtualization, resource scheduling, transaction management, load balancing, concurrency control and memory management. Therefore, security issues for many of these systems and technologies are applicable to cloud computing. All these characteristics of cloud computing make it complicated to provide security in cloud computing. To ensure adequate security in cloud computing, various security issues are presented such as: (1) Access Control Security that; covers *identification*, *authentication* and *authorization* issues; (2) Cloud Infrastructure Security, that covers security issues and attacks that are specific to the cloud infrastructure (IaaS, PaaS and SaaS) and is particularly related with virtualization environment; (3) Data Security, that covers data related security issues including *data migration*, *integrity*, *confidentiality*, and *data warehousing*. (4) Network Security that covers network related security issues including, *network attacks* such as *connection availability*, *denial of Service*, *flooding attack*, *internet protocol vulnerabilities*, *etc*. (5) Security Standards, that covers, *service level agreements*, *auditing* and other *agreements among users*, *service provider* and *other stakeholders*. In this paper we have introduced a comparable analysis for the proposed security issues, the security categories, and the cloud computing services. The paper try to take a first step toward having a dictionary of cloud security attacks that will help to quickly identify and overcome any threat and more important unify the language used between cloud computing, security and cloud users specialists.

## References


1. El-Sofany, H.F., Al Tayeb, A., Alghatani, K., El-Seoud, S.A.: The impact of cloud computing technologies in e-learning. Int. J. Emerg. Technol. Learn. iJET. **8**(11: ICL2012), 37–43 (2013). http://dx.doi.org/:10.3991/ijet.v8iS1.2344
2. NIST: National Institute of Standards and Technology - Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director. "NIST Cloud Computing Standards Roadmap Working Group". NIST Cloud Computing Program, Information Technology Laboratory. NIST Special Publication 500-291, Version 2 July 2013. http://dx.doi.org/:10.6028/NIST.SP.500-291r2
3. Delettre, C., Boudaoud, K., Riveill, M.: Cloud Computing, Security and Data Concealment. IEEE (2011), ISBN: 978-1-4577-0681- 3/11/$26.00 ©2011
4. Technical White Papers. https://support.rackspace.com/white-paper/understanding-the-cloud-computing-stack-saas-paas-iaas/
5. Google: Google Apps. http://www.google.com/apps, 2012
6. Microsoft Corporation. Office Online Services – Hosted in the Cloud – Microsoft Office 365 (2012). http://www.microsoft.com/en-us/office365
7. NetSuite (2012). http://www.netsuite.com/portal/home.shtml
8. Salesforce. Salesforce.com. (2012). http://www.salesforce.com
9. SurveyTool.com. (2012). http://www.surveytool.com
10. Zoho (2012). http://www.zoho.com
11. Cloud Bees. Cloud Platform as a Service for Java Web Apps (2012). http://www.cloudbees.com
12. Engine Yard. Ruby on Rails and PHP Cloud Hosting PaaS (2012). http://www.engineyard.com
13. Google. Google App Engine (2012). http://code.google.com/appengine
14. Heroku. Heroku - Cloud Application Platform (2012). http://www.heroku.com
15. Microsoft Corporation. Windows Azure (2012). http://www.microsoft.com/windowsazure
16. Salesforce. Force.com. (2012). http://www.force.com
17. Amazon. Amazon Elastic Compute Cloud (Amazon EC2) (2012). http://aws.amazon.com/ec2
18. Amazon Simple Storage Service (Amazon S3) (2012). http://mazon.com/s3
19. GoGrid (2012). http://www.gogrid.com
20. Rackspace, The Rackspace Cloud (2012). http://www.rackspace.com/cloud
21. Bluepiit, "Different Types of Cloud Computing Service Models". https://www.bluepiit.com/blog/different-types-of-cloud-computing-service-models/
22. OrBytes Website Admin, (2009). "Cloud Computing". http://www.orbytesolutions.com/services/index.php?option=com_content&view=article&id=55&Itemid=40. Accessed 8 Nov 2010
23. Waxer, B.: "The Benefits of Cloud Computing" (2009). http://www.webhostingunleashed.com/features/cloud-computing-benefits/. Accessed 21 Dec 2010
24. Dans, E.: "Benefits and Disadvantages of Cloud Computing" (2011). http://algramrandomramblings.blogspot.com/2011/01/benefits-and-disadvantages-ofcloud.html. Accessed 14 Mar 2011
25. Kynetix Technology group, "Cloud Computing Strategy Guide" (2009). https://sites.google.com/site/cloudmanual/success-factors. Accessed 2 Dec 2010
26. Armbrust, M., Fox, A., Grith, R., Joseph, A.D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., Zaharia, M.: A view of cloud computing. Commun. ACM **53**(4), 50–58 (2010). https://doi.org/10.1145/1721654.1721672

27. Jensen, M., Schwenk, J., Gruschka, N., Iacono, L.: On technical security issues in cloud computing. In: IEEE International Conference on Cloud Computing, Bangalore, 21–25 September 2009, pp. 109-116 (2009)
28. Gens, F.: New IDC It Cloud Services Survey: Top Benefits and Challenges (2009). http://blogs.idc.com/ie/?p=730
29. Sengupta, S., Kaulgud, V., Sharma, V.S.: Cloud computing security–trends and research directions. In: 2011 IEEE World Congress on Services (SERVICES), pp. 524–531. IEEE, July 2011
30. Hashizume, K., Rosado, D.G., Fernández-Medina, E., Fernandez, E.B.: An analysis of security issues for cloud computing. J. Internet Serv. Appl. **4**(1), 1–13 (2013)
31. Gonzalez, N., Miers, C., Redigolo, F.: A quantity analysis of current security concerns and solutions for cloud computing. In: 3rd International Conference on cloud computing Technology and Science (2011)
32. Rong, C., Nguyen, S.T., Jaatun, M.G.: Beyond lightning: A survey on security challenges in cloud computing. Comput. Electr. Eng. **39**(1), 47–54 (2013)
33. Behl, A., Behl, K.: An analysis of cloud computing security issues. In: 2012 World Congress on Information and Communication Technologies (WICT), pp. 109–114. IEEE, October 2012
34. Shaikh, R., Sasikumar, M.: Security issues in cloud computing: a survey. Int. J. Comput. Appl. **44**(19), 4–10 (2012)
35. Sharif, F., Hafeez, A.: The analysis of cloud computing major security concerns & their solutions. J. Inf. Commun. Technol. **6**(2), 48–53 (2012)
36. Kulkarni, G., Gambhir, J., Patil, T., Dongare, A.A: security aspects in cloud computing. In: 2012 IEEE 3rd International Conference on Software Engineering and Service Science (ICSESS), pp. 547–550. IEEE, June 2012
37. El-Sofany, H.F., Al Tayeb, A., Alghatani, K., El-Seoud, S.A.: The Impact of cloud computing technologies in e-learning, ICL2012, 8(1) (2013)
38. El-Seoud, M.S., El-Sofany, H.F., Taj-Eddin, I.A.T.F., Nosseir, A.F., El-Khouly, M.M.: Implementation of web-based education in Egypt through cloud computing technologies and its effect on higher education. High. Educ. Stud. **3**(3), 62 (2013)
39. El-Seoud, M.S.A., Taj-Eddin, I.A.T.F.: Developing an android mobile bluetooth chat messenger as an interactive and collaborative learning aid. In: Auer M., Guralnick D., Uhomoibhi J. (eds) Interactive Collaborative Learning, ICL 2016. Intelligent Systems and Computing, vol 545, pp. 3–15. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-50340-0_1. http://www.icl-conference.org/icl2016/
40. El-Seoud, M.S.A., Taj-Eddin, IA.T.F.: Beyond android: an essential integration for better utilization, International Conference on Interactive Mobile Communication Technologies and Learning (IMCL2016), pp. 98–102. IEEE (2016). https://doi.org/10.1109/IMCTL.2016.7753780. http://www.imcl-conference.org/imcl2016/
41. El-Seoud, M.S.A., El-Sofany, H.F., Taj-Eddin, I.A.T.F.: Mobile applications and semantic-web a case study on automated course management. Int. J. Interact. Mob. Technol. (iJIM) **10**(3), 42–53 (2016). https://doi.org/10.3991/ijim.v10i3.5770. International Association of Online Engineering. http://online-journals.org/index.php

42. El-Seoud, M.S.A., El-Khouly, M., Taj-Eddin, I.A.T.F.: Strategies to enhance learner's motivation in e-learning environment. In: Proceedings of 18th International Conference on Interactive Collaborative Learning (ICL2015), pp. 944–949. IEEE (2015). https://doi.org/10.1109/ICL.2015.7318154. http://www.icl-conference.org/icl2015/. ISBN: 978-1-4799-8706-1/15 ©2015
43. El-Seoud, M.S.A., El-Sofany, H.F., Karkar, A., Dandashi, A., Taj-Eddin, I.A.T.F., AL-Ja'am, J.M.: Semantic-web automated course management and evaluation system using mobile applications. In: Proceedings of 18th International Conference on Interactive Collaborative Learning (ICL2015), pp. 271–282. IEEE (2015). https://doi.org/10.1109/ICL.2015.7318037. http://www.icl-conference.org/icl2015/. ISBN: 978-1-4799-8706-1/15 ©2015

# Designing and Delivering a Curriculum for Data Science Education Across Europe

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**Abstract.** Data is currently being produced at an incredible rate globally, fuelled by the increasing ubiquity of the Web, and stoked by social media, sensors, and mobile devices. However, as the amount of available data continues to increase, so does the demand for professionals who have the necessary skills to manage and manipulate this data. This paper presents the European Data Science Academy (EDSA), an initiative for bridging the data science skills gap across Europe and training a new generation of world-leading data scientists. The EDSA project has established a rigorous process and a set of best practices for the production and delivery of curricula for data science. Additionally, the project's efforts are dedicated to linking the demand for data science skills with the supply of learning resources that offer these skills. In order to achieve this, EDSA is offering interactive tools for finding learning resources and building personalised learning pathways towards acquiring the skills that are currently in demand.

**Keywords:** Data science · Curricula · Courseware · Skills · Demand analysis Personalised learning pathways

## 1 Introduction

Data has the potential to revolutionise business, government, and society. Data Science methods offer a variety of instruments to create economic and social value, so that decisions are informed by insights and inferences gained from data analyses, while products and services are optimally designed and delivered to meet customer needs. By combining both internally owned and external sources of data, organisations can learn about their processes, accurately plan and target operations, and achieve significant cost savings and productivity gains. This applies to any type of organisation, public or private. For instance, the large amount of data published openly by governmental agencies enables reductions of labour costs and lean management, as well as a better level of accountability and transparency towards citizens and other organisations.

The 'Age of Data' is currently thriving, with data being produced from all industries at a phenomenal rate that introduces numerous challenges regarding the collection,


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storage and analysis of this data. Declared by Harvard Business Review as the "sexiest job of the 21st century" [3], data science skills are becoming a key asset in any organisation confronted with the daunting challenge of making sense of information that comes in varieties and volumes never encountered before. The title is typically linked to a number of core areas of expertise, from the ability to operate high-performance computing clusters and cloud-based infrastructures, to the know-how that is required to devise and apply sophisticated Big Data analytics techniques, and the creativity involved in designing powerful visualizations [8]. Moving further away from the purely technical, organizations are more and more looking into novel ways to capitalize on the data they own [2], and to generate added value from an increasing number of data sources openly available on the Web, a trend which has been coined as "open data".[1] To do so they need their employees to understand the legal and economic aspects of data-driven business development, as a prerequisite for the creation of product and services that turn open and corporate data assets into decision making insight and commercial value.

Nevertheless, data scientists are still a rare breed. Beyond the occasional data-centric startup and the data analytics department of large corporations, the skills scarcity is already becoming a threat for many European companies and public sector organizations as they struggle to seize Big Data opportunities in a globalized world [4]. A McKinsey study estimated already in 2011 that the United States will soon require 60% more graduates able to handle large amounts of data as part of their daily jobs [7]. With an economy of comparable size (by GDP) and growth prospects, Europe will most likely be confronted with a similar talent shortage of hundreds of thousands of qualified data scientists, and an even greater need of executives and support staff with basic data literacy. The number of job descriptions and an increasing demand in higher-education programs and professional training confirm this trend [5], with some EU countries forecasting an increase of almost 100% in the demand for data science positions in less than a decade [9].

Training data scientists and designing curricula that cover data science pose a number of challenges, most notably due to the speed at which this field is changing [6]. Increasing amounts of data lead to challenges around data storage and processing, not to mention increasing complexity in finding the useful story from that data. New computing technologies rapidly lead to others becoming obsolete. New tools are developed which change the data science landscape. These all occur at such a rapid pace that teaching data science requires an agile and adaptive approach that can respond to these changes.

The European Data Science Academy (EDSA)[2] aims at bridging the data science skills gap across Europe. EDSA has established a virtuous learning production cycle for data science in order to analyse the sector specific skillsets for data analysts across Europe's main industrial sectors; develop modular and adaptable curricula to meet these data science needs; and deliver training supported by multiplatform and multilingual learning resources based on these curricula.

The remainder of this paper is structured as follows. First, the EDSA approach for bridging the data science skills gap is presented, with an emphasis on the methodology

[1] http://okfn.org/opendata/.
[2] http://edsa-project.eu.

for the development of curricula and courseware, as well as linking demand with supply. We then discuss the EDSA best practices for the design and delivery of data science curricula. Finally, the paper is concluded and the next steps of this work are outlined.

## 2 Bridging the Data Science Skills Gap

### 2.1 Methodology for the Development of Curricula and Courseware

In order to address the demand for data science skills, a participatory approach has been adopted by EDSA for the design and production of bespoke curricula and courseware (see Fig. 1). This approach builds upon and extends the courseware production process established in the EUCLID project,[3] which was focused primarily on the design and delivery of learning resources about Linked Open Data [10, 11].

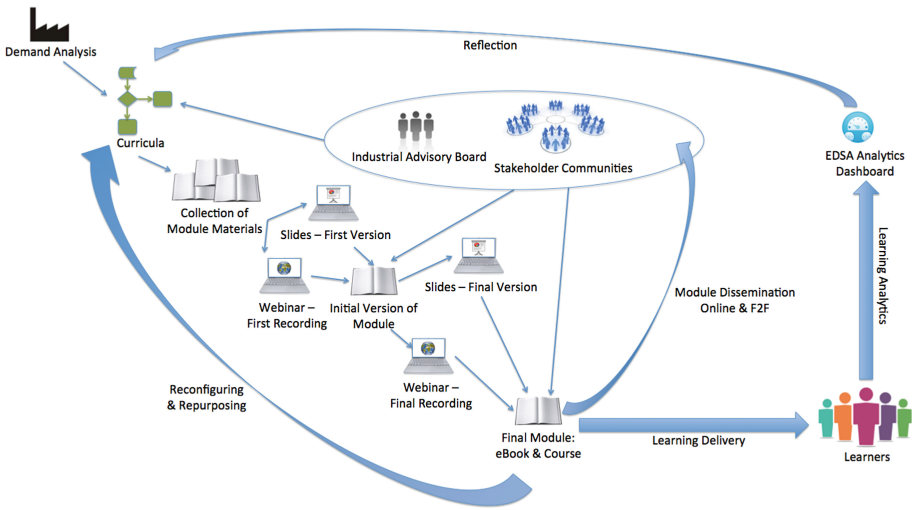


**Fig. 1.** The EDSA production process for curricula and courseware.

EDSA is monitoring trends across Europe in order to assess the demands for particular data science skills and expertise, using automated tools for the extraction of data science job posts, as well as interviews with data science practitioners. The project has also established an Industrial Advisory Board representing a mix of sectors to ensure that project activities continue to meet changes in the demands on data science across Europe.

Starting from the results of this demand analysis and input from the Industrial Advisory Board, we are creating relevant data science curricula to meet the outlined training needs. A multidisciplinary course writing team is developing in parallel a repository of relevant source materials, draft modules that will be placed online, as well as materials

[3] http://www.euclid-project.eu.

for webinars. The draft modules are then iteratively revised based on the feedback received from the Industrial Advisory Board, from the face-to-face training activities, as well as from monitoring the main communication channels used by the communities of stakeholders. The analysed feedback is used to restructure and finalise the module content as an eBook and online course, which are then delivered to the stakeholder communities to support their own training needs and to target learner communities both online and face-to-face.

Learning Analytics have been incorporated into our online delivery, allowing us to collect data related to the learning experiences of our users, which feedback into our curricula design. Based upon the Learning Analytics data and the feedback from our stakeholders, we reconfigure and repurpose modules for different learning contexts initiating new cycles of the production process.

The EDSA curricula and learning resources are tested and evaluated during both development and deployment. This evaluation is targeting pedagogical correctness, fit to sector, as well as the overall quality of the learning experience. Throughout the design, development and deployment of our curricula and learning resources, we actively involve pedagogical experts, who provide advice on the design of the curricula and learning resources. Additionally, the Industrial Advisory Board represents relevant industrial sectors and ensures that the developed learning resources are applicable, relevant and at a suitable skill level to meet industry demand.

Based on the EDSA curricula, the project is developing a courses portfolio, which includes a wide range of data science learning resources adopting a variety of pedagogical models, as well as employing different delivery channels and formats in order to address different learning contexts and audiences. The EDSA courses cover all types of learning contexts, from the traditional face-to-face pedagogical model, to more recent trends in online education:

- *Massive Open Online Courses (MOOCs)*: These are online courses aimed at unlimited participation and open access on the web. They are available on external MOOC platforms, such as FutureLearn[4] and Coursera.[5]
- *Face-to-face courses:* These courses are taught face-to-face. Face-to-face learning (or in-person learning) is any form of instructional interaction that occurs "in person" and in real time between teachers and students or among colleagues and peers.
- *Online courses:* These courses are taught online via Learning Management Systems (LMSs) like Moodle or Sakai. A subset of these courses consists of self-study learning materials available as Open Educational Resources (OERs) [1], which learners can study at their own pace, as there is no predetermined start or end date.
- *Blended courses:* These courses are taught in a blended way (face-to-face and online). Blended learning is a formal education program in which a student learns at least in part through delivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace.

[4] https://www.futurelearn.com.

[5] https://www.coursera.org.

The EDSA courses employ different delivery channels and formats in order to maximise the impact of the EDSA learning materials on the community and bring them closer to as many students and practitioners as possible. In particular, the EDSA courses are available via the courses portal[6] and as an interactive eBook.[7]

The courses portal is the EDSA hub for courses offered both by the project consortium, as well as by external organisations. The portal features a faceted search interface, allowing users to find courses based on a set of search criteria derived from the metadata of the courses. Users, for example, can filter courses by selecting their preferred level of study and the skills they want to acquire from a tag cloud displaying the skills attached to the offered courses.

The EDSA eBook offers an additional delivery medium for the project's courses, targeting primarily tablet devices and mobile phones. In order to widen the audiences reached via different platforms, the EDSA eBook is available both in the iBooks format (supported by iOS and MacOS) and the ePUB format (supported by most desktop and tablet devices). The eBook contains the textual and image/video learning resources of the EDSA self-study courses, as well as self-assessment exercises in the form of quizzes.

## 2.2 From Demand to Supply

Linking the demand for data science skills with the supply of learning resources that offer these skills is crucial for bridging the data science skills gap. Towards this goal, EDSA is developing an interactive dashboard that will enable its users to explore both the current data science skills demand and supply. Users of this dashboard will be able not only to explore the current demand in the data science market, but also find learning materials and training relevant to the skills they will need to secure a specific job position. We are deploying automated tools for extracting data about job posts and news articles in order to present the current state of the European data science landscape. Additionally, users are supported in building personalised learning pathways, consisting of courses and learning materials that will help them reach their learning goals.

In particular, the EDSA dashboard will enable users to:

- View the current demand for data science jobs and skills across Europe.
- Filter demand by required skills and region.
- View trends and statistics regarding data science jobs and skills for a given timeframe.
- Explore the current supply of courses and learning materials that will help them acquire certain skills.
- Build personalised learning pathways towards acquiring certain skills.

Figures 2 and 3 show mock-ups of the EDSA dashboard, which is currently being developed. Figure 2 shows the default view which is deliberately kept as simple as possible. In this view, queries typed into the search box at the top result in a simple list of related data science jobs. Selecting any job results in additional details of the post being displayed. The toolbar below the query entry box allows users to add or

[6] http://courses.edsa-project.eu.
[7] http://courses.edsa-project.eu/mod/page/view.php?id=299.

remove additional views. In Fig. 3, a map and courses view have been selected. Google maps are used for the map view incorporating zoom facilities. Selecting any anchor point in the map brings up details about the job. The courses view shows recommended courses related to the query, which are offered by the EDSA project consortium and external organisations. Additional work on these dashboard views will explore how simple filter mechanisms can be added, allowing users to focus, for example, on a single country, role or industrial sector.

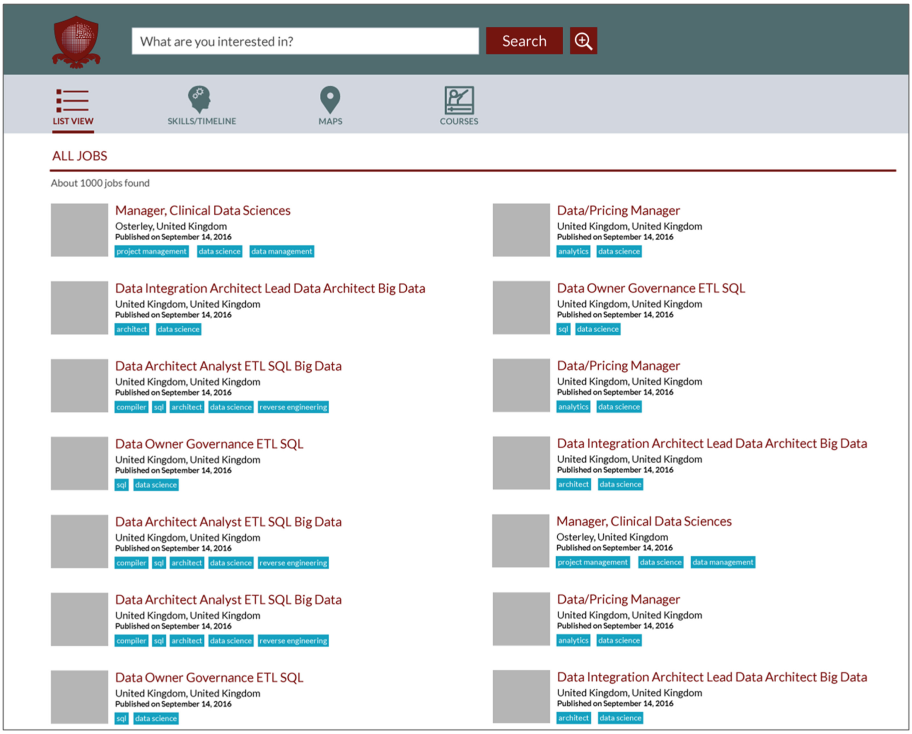


**Fig. 2.** Mock-up of the EDSA dashboard default view.

In order to build their personalised pathways, users of the dashboard will start by identifying the job position that they are after. Based on their selection, the dashboard will present to users the skills that are required for the job position and will recommend courses for acquiring these skills. Following these recommendations, users will then be able to start building their learning pathway towards gaining the required skills.

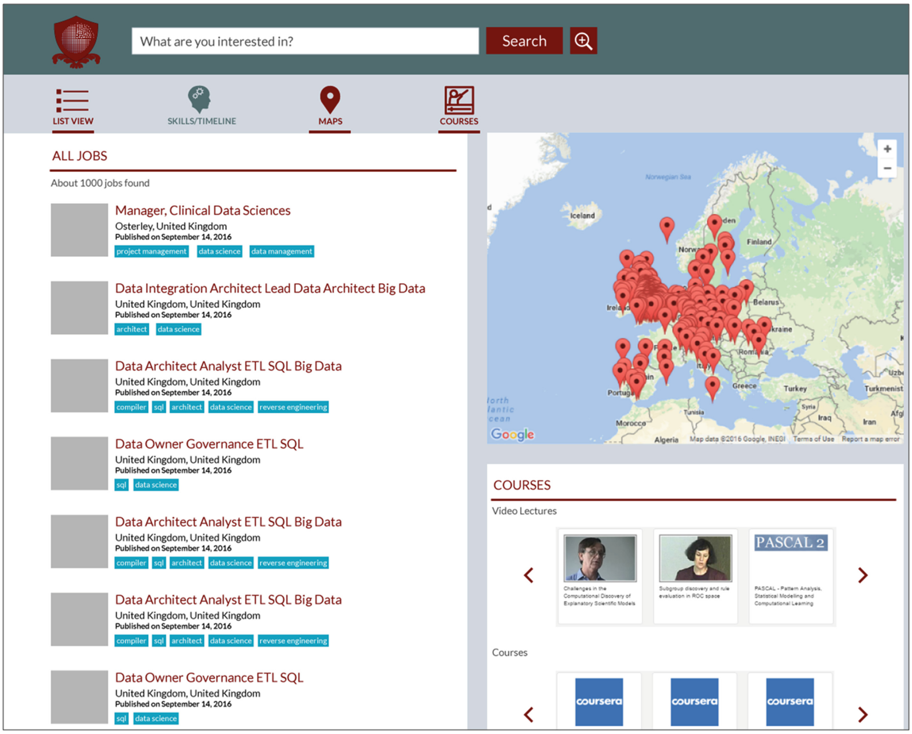


**Fig. 3.** Mock-up of the EDSA dashboard showing a combination of the list view of jobs, a map view of jobs and a view of related courses.

Figure 4 shows the list of data science learning pathways currently offered by the EDSA courses portal.[8] These pathways are based on the EDISON Data Science Framework[9] and consist of recommended data science topics, as well as courses for acquiring certain sets of skills related to these topics. Users can use these pathways as templates in order to build their own pathways by adding courses, monitoring their progress towards completing their pathways, as well as reflecting on the contents of the pathways and on what they have learned, as shown in Fig. 5.

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8 http://courses.edsa-project.eu/course/view.php?id=70.

9 http://edison-project.eu/edison/edison-data-science-framework-edsf.

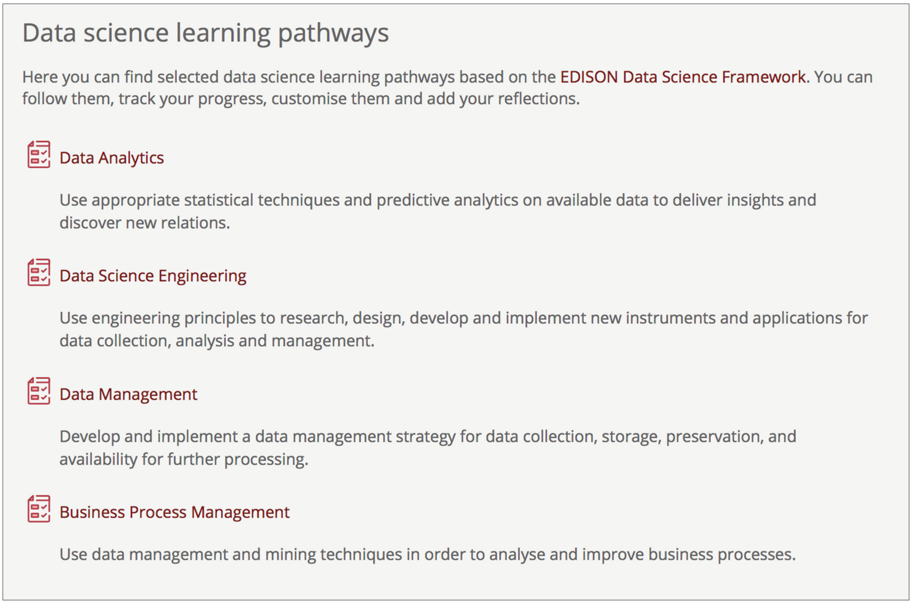


**Fig. 4.** Data science learning pathways in the EDSA courses portal.

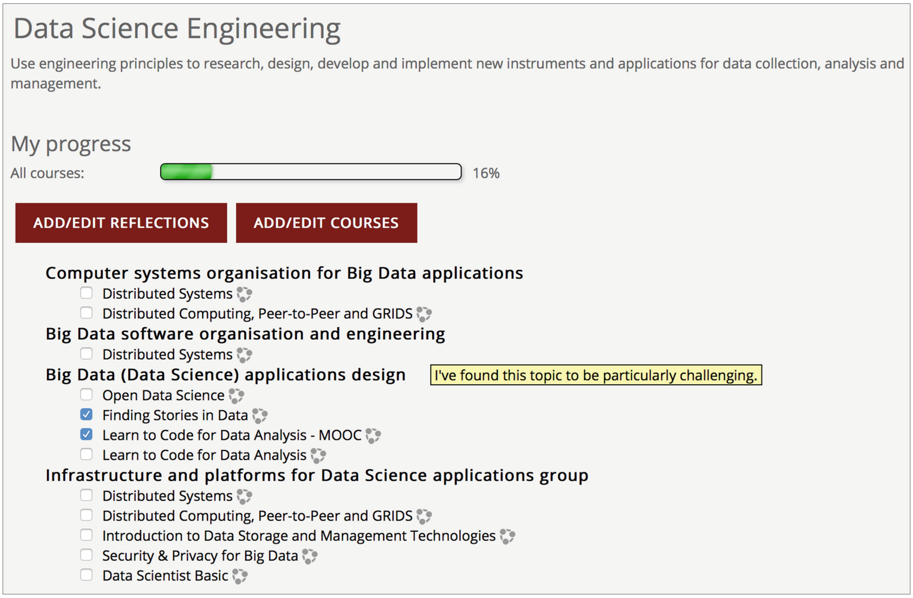


**Fig. 5.** Building a personalised learning pathway.

# 3 Best Practices for the Design and Delivery of Data Science Curricula

Feedback acquired so far from the data science community on the EDSA curriculum has provided us with a valuable insight into the real needs of data practitioners across different sectors. The deployment of the EDSA curriculum and courseware production process has also led us to identify certain challenges associated with the design and delivery of learning resources specifically for data science. We have thus distilled our experiences and lessons learned into a set of best practices, which is outlined in the following sections.

## 3.1 Best Practices for the Design of Data Science Curricula

- *Industry Aligned* – The curriculum is designed in accordance with the expectations of EU industrial sectors connected to data science, providing industry-standard scenarios and tools.
- *Industry Standard Tools* – Our compilation of open source data science tools offer learners experience with tools customary to the industry and their specific sector.
- *Real Data* – Learners utilising this curriculum have access to a number of large-scale open datasets to perform their learned data science skills, enabling real-world data science on real-world data.
- *Open Design* – Our curriculum is designed from user, research, industry and professional recommendations and feedback taken into account from all across the EU, ensuring that the curriculum meets the needs of the industry, academia and the wider market.
- *Expert Provision* – A curriculum that is designed by world-class professional and academic experts in data science.
- *Modular* – The curriculum is flexible and adaptable to educator requirements and the needs of their learners.
- *Transferrable* – Skills learned through the curriculum can be utilised across a range of data science roles, occupations and countries throughout the EU.
- *Concise Learning Goals* – All courses are aligned with clear learning goals depicted by a specific aspect of the data science role. Learning pathways are provided to enable learners to navigate through the content, selecting what is useful to them.
- *Addressing the Whole Data Value Chain* – Data scientists are made aware of the techniques and stages of the whole data science value chain through the use of easily understandable narratives.

## 3.2 Best Practices for the Delivery of Data Science Curricula

- *Multilingual* – Learning resources are delivered across a number of European languages in order to extend their reach and enable others to use our curriculum.
- *Multimodal* – Learning resources are provided in a number of modes to suit skill levels and format preferences, such as MOOCs, eBooks and slide decks.

- *Multi-Platform* – Learning resources are delivered via a wide range of platforms in order to remain accessible and available to a large body of data science learners.
- *Reusable* – Learning resources are released under Creative Commons licenses, allowing the community to reuse, repurpose and republish them.
- *Cutting-Edge Quality* – Learning resources are subject to a series of design iterations that encapsulate the latest research and professional practice, prior to their launch.
- *Reflective and Quantified* – Learning resources are delivered with data and analytics in mind, providing all learners quantified measures and analytics to reflect on their aptitude, skills and strengths.
- *Hands-On* – Learning resources are delivered in a way to emphasise a constructivist hands-on approach, meaningfully applying knowledge to real tools and data.

## 4 Conclusions and Future Work

The EDSA project has established a rigorous process for the production and delivery of curricula and courseware for data science. This process defines a series of iterations in the production of learning resources, with multiple revisions from internal and external stakeholders, in order to ensure high quality in the produced resources. Based on our experiences and lessons learned in designing and implementing the production process, we have established a set of best practices for the design and delivery of curricula for data science. We are also working towards linking the demand for data science skills with the supply of learning resources that offer these skills via tools for exploring the current demand and building personalised learning pathways for acquiring the skills in demand.

The next steps of this work will involve regular reviews and updates of the EDSA curricula and the associated learning resources and learning pathways, so that these outputs reflect the latest trends in the data science market and the current needs of the data science community. By carrying out rigorous Learning Analytics and sourcing input from learners and the wider data science community, we aim to ensure that the learning content and tools on offer from EDSA continue to match the latest demand.

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## References

1. Atkins, D.E., Brown, J.S., Hammond, A.L.: A Review of the Open Educational Resources (OER) Movement: Achievements, Challenges, and New Opportunities. The William and Flora Hewlett Foundation, Menlo Park (2007)
2. Benjamins, R., Jariego, F.: Open Data: A 'No-Brainer' for all. Telefónica Innovation Hub (2013). http://blog.digital.telefonica.com/2013/12/05/open-data-intelligence/
3. Davenport, T.H., Patil, D.: Data scientist: the sexiest job of the 21st century. Harvard Business Review (2012)
4. Domingue, J., d'Aquin, M., Simperl, E., Mikroyannidis, A.: The web of data: bridging the skills gap. IEEE Intell. Syst. **29**(1), 70–74 (2014)

5. Glick, B.: Government calls for more data scientists in the UK. Computer Weekly (2013). http://www.computerweekly.com/news/2240208220/Government-calls-for-more-data-scientists-in-the-UK
6. Hirsh, H.: Data mining research: current status and future opportunities. Stat. Anal. Data Min. **1**(2), 104–107 (2008)
7. James, M., Michael, C., Brad, B., Jacques, B., Richard, D., Charles, R., Angela, H.: Big data: The Next Frontier for Innovation, Competition, and Productivity. The McKinsey Global Institute, New York (2011)
8. Magoulas, R., King, J.: 2013 Data Science Salary Survey: Tools, Trends, What Pays (and What Doesn't) for Data Professionals. O'Reilly (2014)
9. McKenna, B.: Demand for big data IT workers to double by 2017, says eSkills. Computer Weekly (2012). http://www.computerweekly.com/news/2240174273/Demand-for-big-data-IT-workers-to-double-by-2017-says-eSkills
10. Mikroyannidis, A., Domingue, J., Maleshkova, M., Norton, B., Simperl, E.: Developing a curriculum of open educational resources for linked data. In: Proceedings of the 10th annual OpenCourseWare Consortium Global Conference (OCWC), Ljubljana, Slovenia (2014)
11. Mikroyannidis A., Domingue J., Maleshkova M., Norton B., Simperl E.: Teaching linked open data using open educational resources. In: Mouromtsev, D., d'Aquin, M. (eds.) Open Data for Education: Linked, Shared, and Reusable Data for Teaching and Learning, pp. 135–152. Springer International Publishing, Cham (2016)

# BBVPhone: Video Digital Learning for Handicraft

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**Abstract.** In this modern era of information very quickly and easily obtained with available technology. Many ways to get such information from the print media, electronic media and online media. In the everyday life and in the company are required to support information technology so that jobs can be managed and resolved quickly and well. Environment where live many unused items that could be used, but with the lack of knowledge of a person, they consider the goods are not useful. Unwitting that by utilizing unused items that could support the spare time and earn extra income by selling these crafts. The purpose of this study is to develop BBVPhone application, which is utilizing electronic media as a medium of learning videos to learn to make handicrafts from unused goods and as a comparison that to gain knowledge skills do not have to follow a certain course. The method that use to develop the BBVPhone is combining forward chaining and backward chaining method. Another contribution of by optimizing the composition of materials and video tutorials for the purposes of making handicrafts according to the results. Information Systems. It is expected to help the public in the business of unused information into useful handicrafts.

**Keywords:** Multimedia · Handicraft · Learning video

## 1 Introduction

Handicrafts are products or goods made with the skill of the hand and has a function to use and beauty of the commercial value [1]. Crafts which have high quality and function in the everyday life of course the price will be expensive. If someone has the skills and strive to create a product with the skills possessed could be a promising venture [2]. Crafts has two functions, namely the function of wear and decorative functions. Function prioritizes life over the usefulness of such craft goods with little added beauty aspects such as ashtrays, flower pots and pencil boxes, while the decorative function prefers beauty regardless of the usefulness of these items such as sculptures and miniatures [3].

In the neighborhood of unused stuff that is rarely used, like the housewife who does not work, the utilization of unused goods it can to support the activities in the spare time and earn extra income [4]. In the neighborhoods many used items such as cloths and bottles that can be made into useful products such as handicrafts. But people are lazy and do not want to take advantage of that stuff because of lack of knowledge, and they think to gain knowledge of the use of second-hand goods should take a course or training [5].


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Rapid technological developments have helped and easier for people in search of information and resolving problems met or finish the job. Even in everyday life and the company does need the support of information technology to run the job can be completed quickly and well [6, 7]. Information technology is a tool that people use to complete the work [8]. Information technology is a computer system consisting of hardware, software and support a variety of other data. Has a lot of technology creation and the benefits that we feel at this moment that had never before thought to be created [9].

With this opportunity we create new innovations in the use of second-hand goods, namely by studying video that provides a range of video tutorials on crafts. By learning through video many benefits such as, learning more interesting, the video can be repeated at any time, can develop the imagination and overcome the distance and time for busy people [10]. Some mobile applications have been developed before, such as M-Leadership application, this application is not direct counseling services that run on phones [11]. And application development for the M-Psychology junior high school with interactive multimedia approach [12]. Reviewed BBVPhone application uses the incorporation of two methods: forward chaining and backward chaining method, with the optimization that we added to ease users [13].

## 2 The Theoretical Basis

### 2.1 Expert System

Expert System is a computer program designed to model problem-solving that is usually done by humans in the decision or settlement reached similar levels or more. This computer application can be applied in a variety of specific disciplines. While the artificial intelligence is the study of the development of computer-aided program with shows like human intelligence [14].

In its structure, the expert system combining the arguments of inference (inference rules) with specific knowledge base provided by one or more experts in a particular field. The combination of both of these are stored in the computer, which is then used in making decisions for the settlement of certain problems [15].

### 2.2 Forward Chaining and Backward Chaining

Forward chaining is the affirmation of new knowledge, all relevant rules of inductive and deductive waived comprehensively, efficiently make all the knowledge about the current state openly in the system [13, 16].

Forward chaining as its name could be the progress of a system known towards the goal. Forward chaining is an investigative task or problem without having the idea of the result or outcome and work progressively to get it, forward chaining takes several steps or stages to arrive at a solution [17]. Using backward chaining and goal-driven method, starting from the hypothesis, then look for the causes that support from expectations. If the application has a narrow tree results and deep enough, use backward chaining [18, 19].

### 2.3 Video Learning

Instructional video or audio-visual learning medium which is a medium that can give voice and images in a single unit [20]. Video is an electronic signal process that produces a moving image, also called moving pictures have tabled story. Then the tutorial video is a moving picture that tells the story line as a learning tool or instructions that make learning method is more practical and efficient [21, 22].

## 3 Research Methodology

This study posed two stages in research method, namely the collection and implementation of data. Descriptions of two stages in the research method is described below.

### 3.1 Collecting Data

In this study the data obtained by collecting some items that are not used then the goods are used as a creativity that could be worth selling. From the collection of data that have been made to form relationships and rules. Table 1 shows a relationships and crafts basic materials and Table 2 shows a relationships utilities and crafts. Table 3 shows rules production, craft and rules.

**Table 1.** Relationships and crafts basic materials

| Basic materials | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Records CD | * | * | * | * | | | | | | | | | | | | | | | | |
| Bottle | | | | | * | * | * | * | | | | | | | | | | | | |
| Cartons | | | | | | | | | * | * | * | * | | | | | | | | |
| Straws | | | | | | | | | | | | | * | * | * | * | | | | |
| Sticks Ice Cream | | | | | | | | | | | | | | | | | * | * | * | * |

**Table 2.** Relationships utilities and crafts

| Type usability | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goods dosage | * | * | | | * | * | | | * | * | | | * | * | | | * | * | | |
| Decorative goods | | | * | * | | | * | * | | | * | * | | | * | * | | | * | * |

Description:

A Tissue
B Ceramic Pot
C Wall Decoration
D Decorative Lights (Pieces CD)
E Place of Jewelry
F Moneybox
G Decorative Lighting (Bottle)
H Ornamental Flower

I Wall Shelves
J Analog Wall Clock
K Animal Miniature
L Miniature Gas Station
M Curtain Window
N CART
O Miniature Helicopter
P Florist
Q Book Cover
R Bird Cage
S Decorative Lighting (Stick Ice Cream)
T Miniature Houses

There are 20 rules or rules of production in the system but as a sample only included as many as 10 rules only.

**Table 3.** Rules or production rules

| Rule production | Crafts | Rules |
|---|---|---|
| 1 | Tissue | **IF** puck CD **OR** Kleenex box **OR** glue **OR** scissors **THEN** tissue where |
| 2 | Pot Ceramic | **IF** puck CD **OR** Pot flower **OR** glue **OR** scissors **THEN** ceramic pots |
| 3 | Wall Decoration | **IF** puck CD **OR** brush **OR** cat **OR** glue **OR** scissors **THEN** wall hangings |
| 4 | Decorative Lighting (Pieces CD) | **IF** puck CD **OR** Styrofoam **OR** wire **OR** glue **OR** scissors **THEN** Decorative Lighting |
| 5 | Points Jewelry | **IF** Bottle **OR** bolt **OR** nut **OR** small iron **OR** scissors **THEN** jewelry Points |
| 6 | Unique Piggy Bank | **IF** Bottle **OR** zipper **OR** rope **OR** needle **OR** scissors **THEN** Unique Piggy Bank |
| 7 | Decorative Lamp (Bottle) | **IF** Bottle **OR** plastic spoon **OR** glue **OR** scissors **THEN** Unique Piggy Bank |
| 8 | Flower Ornamental | **IF** Bottle **OR** yarn **OR** scissors **OR** brush **OR** paint **THEN** Unique Piggy Bank |
| 9 | Shelving | **IF** cardboard **OR** glue **OR** scissors **OR** brush **OR** paint **THEN** Shelves Wall |
| 10 | Analog Clock | **IF** cardboard **OR** glue **OR** scissors **OR** clockwork **OR** paint **THEN** Analog Wall clock |

## 3.2 Flowchart

BBVPhone applications have supplies and crafts desired choice. For example, the user selects the type of crafts from the bottle and place the classification of goods made with comments three ingredients that he had, with forward chaining reasoning for the classification of storage of goods and handicrafts from the bottle then we got the result that fits namely jewelry. The system will store the jewelry then checked one by one with a backward chaining whether the material is entered in accordance with the composition of jewelry. To close the comments materials fitted with a proprietary material jewelry should be 50% of the composition of the existing materials. When it has been ascertained composition of more than 50% of applications will give a tutorial BBVPhone crafts jewelry box of bottles that can be used by the user as a guide to complete the craft. Figure 1 shows a BBVPhone Flowchart.

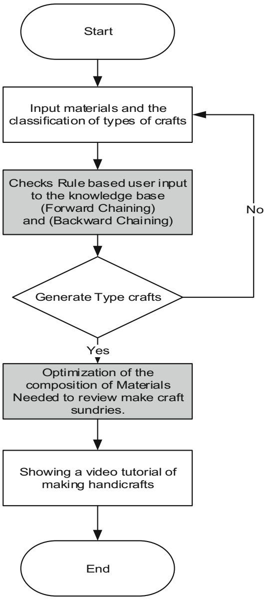


**Fig. 1.** Flowchart

Research BBVPhone application delivers features to optimize the contribution of handicrafts that will be made in accordance with the materials owned by the user. The main difference from earlier research is the study along with optimization of material composition and video tutorials to help the crafting system in accordance with the results of reasoning.

## 4 Result

This section describes the results of tests conducted by the authors. Using proposed method mentioned in the research method, the author has created the application to be tested.

This application was developed using android studio and can run on phones with Android OS version 4.0 and above. The picture below (Figs. 2, 3 and 4) is the connection of BBVPHONE application.


**Fig. 2.** Input Pages Materials owned by users and types of handicrafts


**Fig. 3.** Craft video tutorial page


**Fig. 4.** Pages of ingredients

Figure 2 shows Input Pages Materials owned by users and types of handicrafts, From this advice the system will do the reasoning with forward chaining to find the craft that match the bottle base material with the usage of the wear goods. After the results obtained then the system will do the reasoning again with backward chaining for the composition of supporting materials with the type of craft in accordance with the earlier forward chaining reasoning. The user must have 50% of the supporting material to suit the type of handicraft. This page is a follow-up page from the previous page, user comments will be processed and summarized on this page. This page also has video tutorials for making handicrafts according to user comments materials. Figure 4 shows the complete material optimization that users need to make handicrafts according to user comments.

## 5 Conclusion

BBVPHONE applications can increase user knowledge on how to use the unused items into something worth selling. Which on its use BBVPhone application is used as a video tutorial or video learn to make crafts from utilizing existing unused items around the residence. In this application the search process using two methods at once and performed added calculations to increase the accuracy of handicrafts with materials owned by the user. The shortcomings of this application is the user must use the latest version of the operating system android, for IOS, windows phone, and Blackberry is not yet available. In addition, this application only works on Android OS with version 4.0 and above.

## References


1. García, N., Galeano, G., Bernal, R., Balslev, H.: Management of Astrocaryum standleyanum (Arecaceae) for handicraft production in Colombia. Ethnobot. Res. Appl. **11**, 85–101 (2013)
2. Mogindol, S.H., Bagul, A.H.B.B.P.: Tourists' perceptions about an appealing handicraft. Tourism Leisure Glob. Change **1**, 10–24 (2014)
3. Dlaske, K.: Semiotics of pride and profit: interrogating commodification in indigenous handicraft production. Soc. Semiot. **24**, 582–598 (2014)
4. Makhdoom, T.R., Shah, S.A.A.S., Bhatti, K.-U.-R.: Women's Home-Based and Economic Wellbeing Handicraft Industry: A Case Study Of Pakistan Badin
5. Ibrahim, E., Mousa, A.: Recycle plastic bags into handmade textile waste products. Int. J. Text. Sci. **5**(2), 31–35 (2016)
6. Khaddage, F., Müller, W., Flintoff, K.: Advancing mobile learning in formal and informal settings via mobile app technology: where to from here, and how? Educ. Technol. Soc. **19**(3), 16–26 (2016)
7. Khaddage, F., Knezek, G., Baker, R.: Formal and informal learning: bridging the gap via mobile app technology (MAT). In: 2012 15th International Conference on Interactive Collaborative Learning, ICL 2012 (2012)
8. Luo, Y., Bu, J.: How valuable is information and communication technology? A study of an emerging economy, enterprises. J. World Bus. **51**(2), 200–211 (2016)
9. Qahri-Saremi, H., Turel, O.: School engagement, information technology use, and educational development: an empirical investigation of adolescents. Comput. Educ. **102**, 65–78 (2016)

10. Majekodunmi, N., Murnaghan, K.: In our own words: creating videos as teaching and learning tools **7**(2) (2012)
11. Suyoto, P.T., Gregorius, R.M.: Design and implementation of mobile leadership with interactive multimedia approach. In: Kim, T., et al. (eds.) Multimedia, Computer Graphics and Broadcasting. Communications in Computer and Information Science, vol. 262. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-27204-2_27
12. Suyoto, Suselo T.: Dwiandiyanta Y., Prasetyaningrum T.: New development of M-Psychology for junior high school with interactive multimedia approach. In: Kim, T., et al. (eds.) Multimedia, Computer Graphics and Broadcasting. Communications in Computer and Information Science, vol. 262. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-27204-2_28
13. Kamley, S., Jaloree, S., Thakur, R.S.: Performance comparison between forward and backward chaining rule based expert system approaches over global stock exchanges. Int. J. Comput. Sci. Inf. Secur. **14**(3), 74 (2016)
14. Yinyeh, M.O., Alhassan, S.: Health expert diagnosis and monitoring system software for common medical conditions. Int. J. Comput. Appl. **124**(1), 975–8887 (2015)
15. Nurdiyanto, H., Kuncoro, H.: Sci-Or-005 Expert System for Measuring The Sugar-Content In Sugarcane Using Forward Chaining Method
16. Fiarni, C., Gunawan, A.S., Maharani, R.H., Kurniawan, H.: Automated scheduling system for thesis and project presentation method with forward chaining using dynamic resource allocation. Procedia Comput. Sci. **72**, 209–216 (2015)
17. Marinescu, L., Coles, A.: Non- deterministic planning with numeric uncertainty. In: Frontiers in Artificial Intelligence and Applications (2016)
18. Onda, R.: Development of a learning system for proving the congruence of two triangles by supporting ‘Backward Chaining’. In: Third ICT International Student Project Conference (2014)
19. Guoqi, L., Yuanxun, S., Sheng, H., Bin, L.: An IPC-based prologue design pattern for backward chaining inference integrating into applications or embedded systems. Chinese J. Aeronaut. **27**(6), 1571–1577 (2014)
20. Van Der Meij, H., Van Der Meij, J.: A comparison of paper-based and video tutorials for learning software. Comput. Educ. **78**, 150–159 (2014)
21. Chang, R.-C., Chung, L.-Y., Huang, Y.-M.: Developing an interactive augmented reality system as a complement to plant education and comparing its effectiveness with video learning. Interact. Learn. Environ. **24**(6), 1245–1264 (2016)
22. Zahn, C., Krauskopf, K., Hesse, F.W., Pea, R.: How to improve collaborative learning with video tools in the classroom. Int. J. Comput. Collab. Learn. **7**(2), 259–284 (2012)

# Using Fault Injection for Programming Task Generation

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**Abstract.** In the programming exercise, it is needed to give programming tasks depending on student's knowledge level of programming for more educational effect. However, it is almost impossible to prepare different programming tasks for every student in the big class. This paper presents an idea and a process to introduce fault injection, which has been used for software test, to produce variants of programming tasks depending on student's knowledge level. The system contaminates student's codes with faults intentionally, forces the student to remove them, and examines student's knowledge level. It is confirmed that the prototype implementation of this system works as expected.

**Keywords:** Programming tasks generation · Fault injection
Bloom's taxonomy

## 1 Introduction

Many universities provide programming courses teaching various programming languages such as Java, C/C++, Python, etc., which are used to implement practical ICT systems. These languages are typically taught in the exercise, not in the classroom lecture, by instructors who are responsible for enabling every student to write codes in a satisfactory quality and quantity within a limited time.

Students write codes quite differently even for a simple task. The instructor has to supervise a lot of students with different skill levels at the same time. Time and human resource limitation makes it almost impossible to review codes written by each student in details and give appropriate instructions for him/her. Partial automation of training must be provided to increase educational effects. So far, many researchers have tackled automation of programming exercise. For example, RoboProf [1], problem-solving tool [2], and problem-solving tutor tool [3] provide programming tasks of different levels for many students.

The authors also proposed a system which tracks student's programming activity to alleviate instructor's work in the exercise [4]. In this paper, the authors are addressing another problem which the instructor encounters in the programming exercise.


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Generally, the instructor provides same programming tasks for every student based on a learning plan of the programming course. The programming tasks have limited or no variability; therefore, students can easily make mindless copy-and-paste from articles available in the internet to “accomplish” the tasks. If the instructor does not modify the task every year, the student also can find out the answers of the tasks from ones by students of the previous year. Moreover, the programming tasks are not given to suit each student’s understanding level. The instructor possibly gives too difficult or too easy tasks for the student. Some students may think challenging, but other students may feel unmotivated to practice the assigned tasks, if they are more difficult [2].

The authors employ fault injection techniques to generate variant tasks for different students. Fault injection is a technique that has been used in software testing, which contaminates software under testing with faults intentionally to improve coverage of testing. Moreover, the authors introduce Bloom’s taxonomy to organize programming task assignment depending on student’s understanding level. Bloom’s taxonomy is a hierarchical model defined and used to structure educational objectives, learning activities, and assessments. The authors employ these ideas to generate variant of the programming tasks suitable for each student’s understanding level of programming concepts. The programming environment injects faults into the codes before compilation. The type of faults to be injected is designed along with Bloom’s taxonomy. Namely, the faults to be injected change depending on student’s knowledge level measured by the programming environment.

## 2 Bloom’s Taxonomy

Bloom’s taxonomy is a hierarchical model invented and used to structure educational objectives, learning activities, and assessments [5–7]. Bloom’s taxonomy classifies the knowledge level into six levels: remembering, comprehending, applying, analyzing, synthesizing, and evaluating. Bloom’s taxonomy is general that can be applied to various fields of learning domains; therefore, we should tailor or refine it to fit the learning program we provide.

In programming courses, students learn various concepts of programming languages, such as variables, control structures, data types, classes, functions, *etc.* These concepts are essential knowledge for programming. Generally, the concepts are taught with educational materials by instructors and practiced in programming exercises. In the proposed method, the instructor defines requirements of students that reach each Bloom’s taxonomy level for each programming concept with considering his/her learning program. Table 1 shows example requirements for the concept of the Java variable. The requirements work as a basis of partially automated exercises depending on student’s understanding level.

Upper knowledge levels of Bloom’s taxonomy such as analyzing, synthesizing, and evaluating require students to abstract obtained knowledge and reuse them to solve other problems. Since it is inherently intractable to examine if the student reaches these levels by fully automated manner, the authors do not show example requirements for these levels in Table 1. It never means that we do not have to define requirements for these levels. We should define them; but simply, we need human diagnosis whether students satisfy the requirements.

**Table 1.** Example requirements of students for the Concept of the Java variable

| Bloom's taxonomy | Concept of variables |
|---|---|
| Remembering | The student must remember the names of the following concepts relating to variables:<br>☐ Instance variables<br>☐ Class variables<br>☐ Local variables<br>☐ Basic data types<br>But he/she does not have to know their meanings |
| Comprehending | The student must:<br>☐ understand the concept of the instance variable<br>☐ understand the concept of the class variable<br>☐ understand the concept of the local variable<br>☐ understand any variable has name<br>☐ understand any class or instance variable has visibility to sub or other classes<br>☐ understand any variable has its scope<br>☐ understand any variable is typed<br>☐ understand any variable should be declared before its first use |
| Applying | The student must:<br>☐ be able to declare instance variables of appropriate visibility at appropriate locations in the program<br>☐ be able to declare class variables of appropriate visibility at appropriate locations in the program<br>☐ be able to declare local variables at appropriate locations in the program<br>☐ be able to name a variable appropriately<br>☐ be able to choose an appropriate type for a variable |
| Analyzing | (Out of the scope of this work) |
| Synthesizing | (Out of the scope of this work) |
| Evaluating | (Out of the scope of this work) |

## 3 Fault Injection as a Way of Programming Exercises

Fault injection, a technique that has been used for software testing, contaminates software under testing with faults intentionally to examine and improve coverage of testing. The authors employ the mutation testing technique [8, 9], a kind of fault injection techniques. The mutation testing needs a fault model, which consists of mutant operators and a way of their application to the codes to be tested.

### 3.1 Overall Process of Programming Exercise with Fault Injection

The authors implement an additional function to the programming activity tracking system [4], which the authors presented before. The additional function is to examine student's knowledge level by using the mutation testing technique. The tracking system consists of a server operated in the cloud and clients implemented as an Eclipse plug-in. The plug-in is invoked when the student compiles his/her source codes on Eclipse. It uploads the source codes to the server. The server collects student's codes and help instructors during the exercise.

The authors modify the behavior of this tracking system to let the server inject faults intentionally to examine student's knowledge on various programming concepts. Use case of this additional function is as follows:

1. The student finalizes codes for the programming task and invokes the compiler on Eclipse.
2. The Eclipse plug-in uploads the codes to be compiled to the tracking system server.
3. The tracking system server injects faults suitable for student's knowledge level based on the fault model.
4. The tracking system server sends back the codes with the injected faults to student's Eclipse.
5. Student's Eclipse compiles the codes and shows generated error messages to the student.
6. The student corrects bugs and invokes the compiler again.
7. The Eclipse plug-in uploads the codes to be compiled to the tracking system server.
8. The tracking system server checks if the injected faults are removed and updates student's knowledge level based on the results.
9. Repeat Step 6 to 8.

### 3.2 Establishing a Fault Model

In this paper, the authors focus on using fault injection to examine some knowledge levels of Bloom's taxonomy. Fault injection is never a way to cover all the knowledge levels. As the authors mentioned in Sect. 2, it is difficult to automate examination for upper knowledge levels of Bloom's taxonomy from analyzing to evaluating. The lowest knowledge level, namely remembering, is enough to remember the name of a programming language concept without knowing its meaning well. Since correction of fault injected codes requires at least understanding the meaning of the programing language concept, the remembering level is also out of the scope of the proposed method. Therefore, the authors focus only comprehending and applying levels of Bloom's taxonomy as the target knowledge levels to be examined by fault injection.

We have to define a fault model to examine if the student reaches comprehending or applying levels by mutation testing. To construct a fault model, we first refine each requirement of the understanding level into one or more technical requirements. Student's common errors in programming [10–13] should be considered to elicit technical requirements. For example, the requirement "The student must understand any class or instance variable has visibility to sub or other classes" in Table 1 can be refined as follows:

1. The student must understand that any class or instance variable may have one of access modifiers: private, protected, and public.
2. The student must understand that any class or instance variable without access modifiers has private visibility.
3. The student must understand that private class or instance variable is not accessible from outside of its class.
4. The student must understand that protected class or instance variable is accessible from the class defining the variable or its sub classes. (and more …)

Next, we distinguish the technical requirements refined from the requirements of the understanding level into ones that can be examined automatically and others. For the former, we define "test cases" to examine if the student satisfies them. The test case is mutation of the codes, namely insertion, deletion, or modification of the code. We can assume that the student satisfies the technical requirements and reaches its corresponding knowledge level if he/she correct the codes. For example, for the above-mentioned technical requirements, "The student must understand that any class or instance variable may have one of access modifiers: private, protected, and public," can be examined by removing access modifiers from all the class or instance variables and forcing the student to correct the codes. A set of mutations defined for all the technical requirements forms a fault model.

### 3.3 Mechanism for Fault Injection

Faults are injected by the tracking system server as specified in the fault configuration file in XML. Figure 1 shows an example. The instructor must properly define the programming concepts to be learned, programming language objects relating to the concepts, and ways of fault generation in the XML file.

The second level XML element, <conceptOfVariable> in Fig. 1, specifies the programming concept to be learned. A <keywords> element in it specifies the keywords of the programming language objects relating to the programming concept. The mutation is defined for each keyword of the programming language object. A <keyword> element with sym attribute specifies some ways of fault injection for the keyword sym. A way of fault injection is specified in the <injection> element. The mutation attribute of the <injection> element represents a way of mutation by its value. The possible values are:

– ChangeCases: Changes the cases of the characters forming the keyword randomly.
– Delete: Deletes a part of the keyword specified in its content. For example, <injection mutation="Delete"> [] </injection> means [] is deleted if it is found.
– Insert: Inserts its content after the keyword. For example, <injection mutation="Insert"> [] </injection> means [] is inserted after the keyword.

– Replace: Replaces the keyword with one of the specified candidates. A candidate is specified by the `<candidate>` element in its content. For example,
```
<injection mutation="Replace">
  <candidate> double </candidate>
  <candidate> boolean </candidate>
</injection>
```
means `double` or `boolean` will be replaced in.

The tracking system server selects keywords in the codes randomly and applies mutations selected randomly from `<injection>` elements to them.

```
<programmingExercise>
   <conceptOfVariable>
    <keywords>
      <keyword sym="int">
        <injection mutation="ChangeCases" />
        <injection mutation="Delete">[]</injection>
        <injection mutation="Insert">[]</injection>
        <injection mutation="Replace">
          <candidate>byte</candidate>
          <candidate>long</candidate>
          <candidate>float</candidate>
          <candidate>double</candidate>
        </injection>
      </keyword>
    </keywords>
  </conceptOfVariable>
</programmingExercise>
```

**Fig. 1.** A fault configuration file of the tracking system

## 4 Preliminary Evaluation

In this section, the authors show preliminary evaluation of programming task generation with fault injection on the tracking system. The functionality of the tracking system is tested with some source codes from github.com, an online repository. Evaluation is carried out to check if fault injection to the source codes is performed based on a specific level of Bloom's taxonomy. Students use Eclipse as their development environment. The authors implement an Eclipse plug-in as a client of the tracking system. The plug-in is invoked when the student directs compilation to Eclipse. It sends the source codes to be compiled to the tracking system and receives the codes with injected faults from the tracking system before compilation.

The authors adopt a project on the first page in github.com with "learn Java" as the keywords. As the result, it is confirmed that faults are injected into the source codes of the project successfully.

## 5 Conclusion

It is not easy work to teach programming through giving lectures, providing a variant programming task while at the same time supervising and evaluating the progress of many students at PC rooms. Assistance for the instructor is needed to identify the students with different programming talents and skills concurrently. In this work the authors employed the fault injection to generate a variant programming task based on student's knowledge level of programming concepts. We also introduce Bloom's taxonomy to organize the programming tasks. Student's programming environment injects the faults into the codes on compilations. The type of faults to be injected is designed following the Bloom's taxonomy. The faults to be injected changes depending on student's knowledge level measured by the programming environment.

In the future work, the authors are planning to test to real students or real situation. The authors are also going to address another problem to assess student's programming skills. The current assessment is based on the codes or reported submitted by the student, not in real time and not ongoing assessment; therefore, the instructor cannot improve the way of instruction responsively. The instructor also cannot assess all students in details, especially for a bigger class which the assessment needs a huge amount of effort.

## References


1. Daly, C., Horgan, J.M.: An automated learning system for Java programming. IEEE Trans. Educ. **47**(1), 10–17 (2004)
2. Taheri, S.M., Sasaki, M., Ngetha, H.T.: Evaluating the effectiveness of problem solving techniques and tools in programming. In: 2015 Science and Information Conference (SAI), pp. 928–932 (2015)
3. Kumar, A.N.: Learning programming by solving problems. In: Informatics Curricula and Teaching Methods, pp. 29–39. Springer (2003)
4. Habibi, B., Nakanishi, T., Fukuda, A.: Student's programming activity tracking system to help instructors of the programming exercise. In: 2016 IEEE Region 10 Symposium (TENSYMP), pp. 89–94 (2016)
5. Anderson, L.W., Sosniak, L.A.: Bloom's taxonomy: a forty-year retrospective. Ninety-third Yearbook of the National Society for the Study of Education. University of Chicago Press, Chicago (1994)
6. Oliver, D., Dobele, T.: First year courses in IT: a Bloom rating. J. Inf. Technol. Educ. **6**, 347–360 (2007)
7. Scott, T.: Bloom's taxonomy applied to testing in computer science classes. J. Comput. Sci. Coll. **19**(1), 267–274 (2003)
8. Ma, Y.-S., Offutt, J., Kwon, Y.R.: MuJava: an automated class mutation system. Softw. Test. Verification Reliab. **15**(2), 97–133 (2005)
9. Delamaro, M.E., Maidonado, J.C., Mathur, A.P.: Interface mutation: an approach for integration testing. IEEE Trans. Softw. Eng. **27**(3), 228–247 (2001)
10. Ahmadzadeh, M., Elliman, D., Higgins, C.: An analysis of patterns of debugging among novice computer science students. ACM SIGCSE Bull. **37**(3), 84–88 (2005)

11. Hristova, M., Misra, A., Rutter, M., Mercuri, R.: Identifying and correcting Java programming errors for introductory computer science students. ACM SIGCSE Bull. **35**(1), 153–156 (2003)
12. Jackson, J., Cobb, M., Carver, C.: Identifying top Java errors for novice programmers. In: 2005 35th Frontiers in Education Conference, p. T4C (2005)
13. Mow, I.C.: Analyses of student programming errors in Java programming courses. J. Emerg. Trends Comput. Inf. Sci. **3**(5), 739–749 (2012)

# A Mixed-Reality Environment for Personalised and Collaborative Learning in Science and Engineering

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**Abstract.** Mixed reality environments as in-betweens of real-world and virtual-reality (VR) environments are created by combining real world objects with computer generated ones. In general, mixed-reality along with VR technology provides innovative ways of showing relationships and connections in the real world, mainly by complimenting real objects with additional information (text, audio and video overlays). In Science Technology and Engineering (STE) disciplines, collaborative learning is about learners working together in teams or groups on structured learning tasks, that typically have a clearly defined goal and are arranged in such a manner that all members of the team are involved. A collaborative approach builds individual and group accountability in each learner as well as one or more soft skills such as communicating with peers, managing resources and the ability to make decisions. This paper presents the use of mixed-reality environments for personalised learning along with two approaches based on message passing paradigms for implementing collaborative learning in mixed-reality environments. The first approach shows the use of a pair of geographically distant mixed-reality environments for remote collaborative learning, while the second approach show multiple (independent) mixed-reality tools synchronised for co-located group work/learning. The statistical analysis of a research study with over 70 respondents from STE disciplines who were exposed to mixed-reality tools developed using mobile technology is also presented and discussed in the context of collaborative work within mixed-reality environments. The contributions includes unique implementations of mixed-reality based collaborative learning environments capable of providing similar experience to that obtained from traditional real-world environments.

**Keywords:** Mixed-reality · Collaborative-learning


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## 1 Introduction

In collaborative learning learners cooperatively work together in teams or groups on structured learning tasks that typically have a clearly defined goal and are arranged in such a manner that all members of a team or a group are involved. Generally, participation in these task requires both individual and group accountability from each team-member for the development of one or more soft skills such as communicating with peers, managing resources (time) and the ability to make or modify decisions based on contributions of others. In collaborative learning, it is important for the team members to meet periodically to promote individual and collective development/improvements. Some examples of structured learning tasks in Science and Engineering includes teams/groups for completing assignments, report writing, just studying for an examination or test [12] and joint research-work towards subject based projects and problems. Instructors (teachers) as educators play a less central role in collaborative learning because learners take more responsibility for their own learning [24]. The knowledge acquired by each learner is uniquely constructed from individual prior experiences, interactions with other learners and their collective experiences. This implies that the knowledge acquired by a learner is growing over time and is also individually personalized to the particular group of collaborating learners.

Mixed reality environments as in-betweens of real-world and virtual-reality (VR) environments are created by combining real world objects with computer generated ones. The Augmented Reality (AR) form of mixed-reality is already present in many every-day applications, such as live-television broadcast of sports events [3]. In general mixed-reality along with VR technology provides innovative ways of showing relationships and connections in the real world. Many educational applications of mixed-reality environments including [28,29] work by complimenting real objects with additional (passive) information (text, audio and video overlays). While, computers and other ICT tools are regularly used in learning and research, sometimes for processing, transformations or presentations [7]; mixed-reality environments are better suited for integrating research data/outputs across a variety of media formats for enhanced presentation of real-world objects during the learning process [9]. Most examples of mixed-reality environments show good support for personalised learning where collaboration is typically limited to the shared use of a single (common) mixed-reality tool for visualisation and learning by all learners co-located in the same room/environment.

This paper examines the use of mixed-reality environments for collaborative and personalised learning and is structured as follows: Sect. 2 reviews relevant concepts, standards and goals of collaborative and personalised learning applicable to mixed-reality environments. While, Sect. 3 presents two approaches based on message passing paradigms for implementing collaborative learning in mixed-reality environments. Section 4 discusses the findings and statistical analysis of results from a questionnaire based study of mixed-reality environments in Science and Technology before concluding in Sect. 5.

## 2 Background

In most Science and Engineering programmes, teaching (lecturing and possibly with additional tutoring) would be carried out before the learners are exposed to collaborative learning tasks designed to illustrate or illuminate the prior taught (or learnt) theories and concepts. For example, in capstone projects, learners are grouped in small teams of up to eight individuals to undertake a given project and informally exchange and share information amongst themselves. Here, learners may also acquire additional soft skills in the area of collaborative engineering design [24]. These structured learning tasks may also require learners individually plan and implement some aspects practically and/or subsequently produce an individual final written report as a terminal part of the training.

An alternative to capstone projects involves the introduction of problems before the classes (lectures and tutorials) on relevant topics are held. The expectation is that the learners having an immediate objective or purpose would then study/investigate topics deeper seeking to discover answers to the problems as part of the learning process that would occur during subsequent lectures and tutorials [16]. Sometimes, the teacher or instructor also intertwines the problem or project into the normal class (or alongside the normal class) lessons on the theory, as this encourages learners to readily connect and associate the (highlighted by instructor or teacher) facts and other theoretical concepts to potential or actual solutions to the problem as soon as they learn them.

Capstone projects in collaborative learning may provide a rather limited perspective of the real-world, that does not reflect the actual situations occurring in a real industry environment, even when the projects (or challenges) are provided directly or in-directly by a relevant industry partner. Another approach to collaborative learning involves the learners also participating in the running of a simulated company or industry specially set-up around the project. The learners are fully involved in all aspects of the simulated company including the determination of the various positions available and other aspects of the company structure. The learners would prepare their own curriculum vitae and apply for the various positions in the simulated company. Subsequently, they also participate in the evaluation and selection process for filling the various positions. The chief executive officer in the simulated company is played by an instructor or tutor acting only as a passive advisor providing limited guidance to the learners. The simulated company usually has about thirty staff (learners) who would form several operational teams required to complete the project work [6].

Another example of collaborative learning, involves communication and exchange of ideas across different generations of scientists and engineers. As [27] pointed out, the problems and challenges faced in industry as well as the associated solutions are hardly static and the use of mentors across generation would ensure the growth and exchange of know-how between industry (older engineers as mentors) and young/upcoming engineers. A commonly used technique is for individual learners to spend a period (up-to 6 months) of training (attachment) with some industry partner acquiring working (practical) knowledge from the older scientists or engineer [34]. Learners would then subsequently or periodically meet in organised research seminars/forums to collectively present, share and exchange highlights from their individual experiences as well as collectively brainstorm to address identified challenges, possibly in the presence of older scientists and engineers.

### 2.1 Mobile Mixed Reality

Mixed-reality system combine real world objects with computer generated ones within an apparently seamless viewing space while allowing some user interactions with one or more computer generated objects in real-time. Mixed reality technology is potentially limitless in its ability to provide an enhanced view of the world or environment around a user and by extension its ability to enhance derivable learning from surrounding environment. Technologically, mixed reality systems usually require a hardware capture device such as a camera, combined with a processing element running a suitable mixed reality software application that performs the required transformations in real-time before display on a hardware output device such as a display-screen.

According to [25], the two main types of mixed reality are Augmented Reality (AR) and Augmented Virtuality (AV) [30]. In AR, the resulting view is predominantly made of real objects while in AV, the resulting view is predominantly made up of computer generated (virtual) objects. Most works and examples of mixed reality systems tend to focus heavily on the visual domain, at the expense of other forms of such as auditory augmentation: which involves the delivery of sound based augmented via speaker devices (arranged spatially) and haptic augmentation: which involves the delivery of tactile augmentations (touch, pressure or vibrations) via small motors. In mixed reality environments, visual, auditory and haptic augmentations may be used all-together as outputs although, the visual form is more commonly encountered [20]. Auditory and haptic augmentations in mixed reality environments can be used to support learning especially for the visually challenged learners [13].

Up on till a few years ago, mixed reality was considered applicable within certain sectors, the advent of powerful mobile devices such as tablets and smartphones has completely revolutionized mixed reality research and it is now seen as a powerful tool capable of supporting both formal and informal learning in science and engineering [9]. There are already many examples of educational use of mixed reality technology including: the training of operators in specialized processes [15]; training operators in system maintenance [33]; medical training [1]; story telling (Magic Book) [5]; educating learners about cultural heritage, architectural design and urban planning [23]. A mixed reality application for mechanical engineering allows users to interact with a web based 3D model of piston [22] and the augmentation of remote laboratories in electrical engineering [2]; supporting laboratory experiments in electronics [31], power generation [28] and communications engineering [29].

In education, the use of mixed reality applications on mobile devices is driving new frontiers in personalised learning especially in tailoring learning-experience to the individual learner. That is, within a mixed reality environment, in addition to the on-demand access (delivery) to learning objects, a learner could also choose the means and levels of interacting with the learning objects. For example, in the Magic story book, a learner can choose to interact with three dimensional (3D) graphical animations of characters from the story [5]. It is also clear that using learner owned mobile devices also promotes personalisation. Collaborative learning in mixed reality environments is obtained mainly through the shared use of a common viewing device. That is, learners working in small groups participate in the collective use of a single mixed reality tool and informally exchange and share information among themselves as each one had a different viewing angle. An alternative approach is the serial use of a single mixed reality tool, where each learner is responsible for individual use, there is some informal exchange or sharing or passing of hints and other information from one learner to the next. The next section discusses the collaborative use of a pair of mixed reality environments along with the synchronised use of multiple mixed reality tools within a single environment.

## 3 Collaborative Mixed Reality Environments

The previous section examined existing approaches to collaborative learning in STE disciplines and mixed reality environments. This section presents two additional approaches for collaborative learning within mixed-reality environments based on concepts from High Performance Computing. These approaches consider only the concurrent use of more than one mixed reality environments.

### 3.1 Paired

Figure 1 shows two mixed reality tools (labelled A and B, respectively) paired for collaborative use. A key requirement is that both mixed reality tools would be very similar in composition, that is using the marker and application concurrently, even if the physical hardware devices are different. That is, A could be a smart phone, while B could be a tablet device. It is clear that the paired environments or tools may be located at great geographic distances as long as the resulting latency is small enough. Within, this paired collaborative environment, once the connection is established between the pair, information about changes in objects resulting from user manipulations (or otherwise) are transferred between them. For example, rotating an object (knob) in A would cause the same knob to rotate in B.


**Fig. 1.** Paired mixed reality tools/environments

In this approach, collaboration is through direct communication between a pair of mixed-reality environments over a common channel or network. The formatting of messages and subsequent direct exchange of data/information between two entities may be implemented within a mixed reality application as proprietary software code or through the use of third-party libraries. The well-known Message Passing Interface (MPI) libraries in High Performance Computing (HPC) includes basic functions for establishing a point-to-point communication model for the exchange of data between two entities. Apart from MPI or similar tools, there are also standards (e.g. REST) and libraries for data communication that include suitable routines/functions for initializing a communication channel, establishing a connection and performing the transfer of data over a suitable network such as the internet using well-defined formats.

The paired collaborative learning mixed reality environment is well suited for one-on-one joint exploration of objects; guiding and teaching specialized processes such as medial training, etc.

### 3.2 Broadcast

Moving beyond a paired, one-to-one or point-to-point collaborative learning model, a one-to-many model of communication is required especially during group collaboration as shown in Fig. 2, where, a mixed reality tool (A) is communicating with other tools (B, C, D and E). Similar to the paired collaborative environment, the tools must be very similar in composition. In MPI and similar libraries, one-to-many communications within a common group is typically performed using a broadcast model. That is each entity sends a single message that is received by all other members of the group without a sender individually transmitting the same message to each member entity. The one-to-many model may be extended to a many-to-many situation, where a member can dynamically switch between sending and receiving; that is, acting as a sender broadcasting

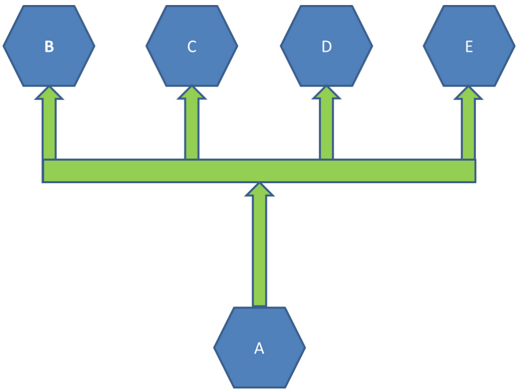


**Fig. 2.** Broadcast (one to many) mixed reality tools/environments

its message to all other members or acting as recipient receiving messages from other senders.

Consider a group of mixed-reality visualisation tools which are co-located within a room possibly all pointed at the same reference marker. It is expected that each tool presents an independent windowed-view into the mixed-reality environment that is unique based on angular orientation and direction. Using the broadcast approach, a synchronised collaborative learning environment is created where user manipulations performed on any member device that results in changes to objects would be broadcast to all other mixed reality tools in the room. Locating members of the group mixed reality tools at great distances is also possible although there may be some difficulties with compensating for variable round-trip delays or latency that may exist from one location to another.

The synchronised collaborative learning mixed reality environment is well suited for one-on-many group exploration of objects; demonstrating and teaching specialized processes such as medial training, etc. While a many-to-many form may be implemented, it could easily become chaotic.

## 4 Results

Many users are increasingly exposed to mixed reality technology and environments during day-to-day activities such as using street navigation systems and viewing sporting events on television. There is also a growing availability of mixed reality tools/applications for mobile devices such as smart phones and tablets, where they are deployed and used in a personalised or non-collaborative context.

This section presents results from a questionnaire based study carried out to investigate experiential attitude towards using mixed reality based collaborative environments created from mobile technologies. There were a total of 84 respondents from 5 different STE disciplines as shown in Table 1.

The survey was designed as a set of closed items or questions and responses were collected based on a 5-level Likert scale for analysis after associated exposure to mixed-reality tools/environments (either paired or broadcast) developed using mobile technology. A summary of the collected responses is presented in Table 2.

As shown in Table 2, the respondents who were all learning within traditional classrooms environments (without blended learning) were not very familiar with the academic use of social networks or similar tools. However, they claimed to be more familiar with the academic use of mixed reality tools. The collected data suggests that majority of learners did not find the collaborative environments confusing and also prefer collaborative-work over working in online groups, forums and social networks. This may be attributed to the sharing and exchange of useful information that occurs during collaborative learning and is in line with the findings of other authors including [6,10]. However, it is noted that most of the respondents were familiar with working collaboratively during their laboratory, practical and/or tutorial classes.

**Table 1.** Profile of the respondents

| Demographic profile | Frequency | Percentage (%) |
|---|---|---|
| **Departments** | | |
| Computational Science | 13 | 15.48 |
| Computer Science | 1 | 1.91 |
| Engineering | 33 | 39.29 |
| Mathematics | 6 | 7.14 |
| Physics | 25 | 29.76 |
| *Data not provided* | 6 | 7.14 |
| **Role** | | |
| Students | 75 | 89.29 |
| Lecturers | 5 | 5.95 |
| *Data not provided* | 4 | 4.76 |
| **Student level** | | |
| 1st year | 33 | 39.29 |
| 2nd year | 5 | 5.95 |
| 3rd year | 14 | 19.44 |
| Masters | 16 | 19.05 |
| Ph.D | 4 | 4.76 |
| *Data not provided* | 12 | 14.29 |
| **Age range** | | |
| 16–20 | 36 | 42.86 |
| 21–24 | 17 | 20.24 |
| 25–29 | 12 | 14.29 |
| 30–35 | 10 | 11.90 |
| Over 35 | 5 | 5.95 |
| *Data not provided* | 4 | 04.76 |

**Table 2.** Summary table of responses

| Questionnaire item | Yes (%) |
|---|---|
| Do you participate regularly in on-line group/forums/social networks and discussion sites? | 27.38 |
| Are you familiar with mixed reality environments? | 30.37 |
| Do you find the mixed reality environments confusing? | 19.52 |
| Did you like the mixed reality collaborative environments? | 72.62 |

The study presented here was limited in scope as respondents were asked to only consider academic use of on-line tools and also learner preference between paired and broadcast collaborative environments was not investigated.

### 4.1 Discussion

Traditionally, mixed reality environments created with mobile technology are non-collaborative in nature as they are designed to by used by a single individual. As discussed in Sect. 2, some level of collaborative use of a single mobile device by two or more individuals is possible but quite limited as one learner typically performs all the tasks/actions while others play a mostly passive role. The paired and broadcast mixed reality collaborative environments presented in Sect. 3 support the synchronous use of a mixed reality application on multiple devices geographically distant from one-another for creating a collaborative environment. Conceptually the resulting environments are similar to well-known collaboration concepts such as the use of study-partner and discussion groups, respectively. The discussed paired environment is also suitable for use in a one-on-one instructor-learner collaboration and provides for joint visualisation and manipulation of objects. While, the broadcast environment is more suited for a one-to-many (instructor-to-group) collaboration. Here, the manipulations of objects on the primary device are replicated to all other devices.

Augmented Reality (AR) supplements reality through displaying useful information, not directly detected by the senses of a user, helping the user to perform real-world tasks and facilitating the understanding of complex scenarios [4]. It is used to describe an environment where the physical world is enhanced by adding computer-generated objects using computer vision methods to make them appear as if they co-exist in the same dimension [32]. It is crucial for learners to engage in experimentation in science and engineering. There has been the question of discerning the best approach, utilizing either the physical or virtual laboratories. Various studies have shown that students who conducted both physical and virtual experiments outperformed those in the physical-alone and virtual-alone conditions, capitalising on the benefits of each approach [8,11,17,18,21,26,35]. The virtual laboratory settings test and consolidate conceptual knowledge while the physical laboratory settings test and consolidate abilities relating equipment handling and use.

In a recent study [19], Augmented and Virtual Reality, along with adaptive technologies in learning and maker-spaces have been shown to be among the list of trends reflecting the mixing of realities experimented in aspects of society, such as communication and entertainment. Current efforts could be directed at improving current markers used in AR and the development of markerless systems portability and enhanced user experience.

## 5 Conclusion

This paper on collaborative learning in mixed reality environments presents two new approaches for moving beyond a basic single environment sharing model.

The first approach shows the use of a pair of geographically distant mixed-reality environments for remote collaborative learning, while the second approach show multiple (independent) mixed-reality tools synchronised for co-located group work/learning. To our knowledge, this work is unique in relating collaborative learning on mixed-reality environments to established message passing concepts/systems from High Performance Computing (HPC). The collected data from survey of learners suggests a clear preference for collaborative experience compared to well-known online groups, forums and social networks.

We note that in education, use of the proposed mixed-reality platform presents a challenge for teachers and instructors. As stated, learning within technology creates a pedagogical shift that requires teachers to think about measuring outcomes in non-traditional ways [14]. This extends from acceptance and inclusion into their everyday practice, right through to assessment and other pedagogical issues. This makes it necessary to evaluate students' learning gains and propose adequate mechanisms for assessment.

The use of mixed reality in such environments has the potential to enhance level of interaction of learners on any of these platforms and increase collaboration for increased understanding of concepts and completion of projects and tasks.

## References

1. Albrechta, U., Nolla, C., von Jan, U.: Explore and experience: mobile augmented reality for medical training. In: Lehmann, C.U., Ammenwert, C., Nahr, C. (eds.) MEDINFO 2013: Studies in Health Technologis and Informatics, vol. 192, pp. 382–386. IMIE & IOS Press, Copehegen (2013)
2. Andujar, J.M., Mejias, A., Marquez, M.A.: Augmented reality for the improvement of remote laboratories: an augmented remote laboratory. IEEE Trans. Educ. **54**(3), 492–500 (2011)
3. Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., MacInTyre, B.: Recent advances in augmented reality. IEEE Comput. Graph. Appl. **21**(6), 34–47 (2001)
4. Azuma, R.T.: A survey of augmented reality. Presence-Teleoperators Virtual Environ. **6**(4), 355–385 (1997)
5. Billinghurst, M., Kato, H., Poupyrev, I.: The MagicBook - moving seamlessly between reality and virtuality. IEEE Comput. Graph. Appl. **21**(3), 6–8 (2001)
6. Broman, D., Sandahl, K., Baker, M.A.: The company approach to software engineering project courses. IEEE Trans. Educ. **55**(4), 445–452 (2012)
7. Canessa, E., Zennaro, M.: A mobile science index for development. Int. J. Interact. Mob. Technol. **6**(1), 4–6 (2012)
8. Climent-Bellido, M.S., Martnez-Jimnez, P., Pontes-Pedrajas, A., Polo, J.: Learning in chemistry with virtual laboratories. J. Chem. Educ. **80**(3), 346 (2003)
9. Davidsson, M., Johansson, D., Lindwall, K.: Exploring the use of augmented reality to support science education in secondary schools. In: Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education, pp. 218–220. IEEE Computer Society (2012)
10. Davis, C.E., Yeary, M.B., Sluss, J.J.: Reversing the trend of engineering enrollment declines with innovative outreach, recruiting and retention programs. IEEE Trans. Educ. **55**(2), 157–163 (2012)

11. de Jong, T., Linn, M.C., Zacharia, Z.C.: Physical and virtual laboratories in science and engineering education. Science **340**(6130), 305–308 (2013)
12. Felder, R.M., Woods, D.R., Stice, J.E., Rugarcia, A.: The future of engineering education II. Teaching methods that work. Chem. Eng. Educ. **34**(1), 26–39 (2000)
13. FitzGerald, E., Adams, A., Ferguson, R., Gaved, M., Mor, Y., Thomas, R.: Augmented reality and mobile learning: the state of the art. In: Specht, M., Sharples, M., Multisilta, J. (eds.) 11th World Conference on Mobile and Contextual Learning (mLearn 2012), pp. 62–69. CEUR, Helsinki (2012)
14. Gardner, M., Elliott, J.: The immersive education laboratory: understanding affordances, structuring experiences, and creating constructivist, collaborative processes, in mixed-reality smart environments. EAI Endorsed Trans. Future Intell. Educ. Environ. **14**(1), e6 (2014)
15. Henderson, S.J., Feiner, S.: Evaluating the benefits of augmented reality for task localization in maintenance of an armored personnel carrier turret. In: Proceedings of IEEE ISMAR-AMH, pp. 135–144. IEEE (2009)
16. Hosseinzadeh, N., Hesamzadeh, M.R.: Application of project-based learning (PBL) to the teaching of electrical powersystems engineering. IEEE Trans. Educ. **55**(4), 495–501 (2012)
17. Huppert, J., Lomask, S.M., Lazarowitz, R.: Computer simulations in the high school: students' cognitive stages, science process skills and academic achievement in microbiology. Int. J. Sci. Educ. **24**(8), 803–821 (2002)
18. Jaakkola, T., Nurmi, S., Veermans, K.: A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts. J. Res. Sci. Teach. **48**(1), 71–93 (2011)
19. Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., Hall, C.: Horizon report 2016: Higher education edition (2016). http://cdn.nmc.org/media/2016-nmc-horizon-report-he-EN.pdf. Accessed 9 Jul 2017
20. Kilby, J., Gray, K., Elliott, K., Waycott, J., Sanchez, F.M., Dave, B.: Designing a mobile augmented reality tool for the locative visualization of biomedical knowledge. In: Lehmann, C., Ammenwert, C., Nahr, C. (eds.) MEDINFO 2013: Studies in Health Technologis and Informatics, vol. 192, pp. 652–656. IMIE & IOS Press, Copenhagen (2013)
21. Kollffel, B., de Jong, T.: Conceptual understanding of electrical circuits in secondary vocational engineering education: combining traditional instruction with inquiry learning in a virtual lab. J. Eng. Educ. **102**(3), 375–393 (2013)
22. Liarokapis, F., Mourkoussis, N., White, M., Darcy, J., Sifniotis, M., Petridis, P., Basu, A., Lister, P.F.: Web3D and augmented reality to support engineering education. World Trans. Eng. Technol. Educ. **3**(1), 11–14 (2004)
23. Loscos, C., Widenfeld, H.R., Roussou, M., Meyer, A., Tecchia, F., Drettakis, G., Gallo, E., Martinez, A.R., Tsingos, N., Chrysanthou, Y., Robert, L., Bergamasco, M., Dettori, A., Soubra, S.: The create project: mixed reality for design, education, and cultural heritage with a constructivist approach. In: The Second IEEE and ACM International Symposium on Mixed and Augmented Reality, pp. 282–283. IEEE (2003)
24. Macias, J.A.: Enhancing project-based learning in software engineering lab teaching through an e-portfolio approach. IEEE Trans. Educ. **55**(4), 502–507 (2012)
25. Milgram, P., Takemura, H., Utsumi, A., Kishino, F.: Augmented reality: a class of displays on the reality-virtuality continuum. Telemanipulator Telepresence Technol. **2351**, 282–292 (1994). SPIE

26. Olympiou, G., Zacharia, Z.C.: Blending physical and virtual manipulatives in physics laboratory experimentation. In: Topics and Trends in Current Science Education, January 2014
27. Onime, C., Uhomoibhi, J.: Engineering education in a developing country: experiences from Africa. In: 2012 15th International Conference on Interactive Collaborative Learning (ICL), Villach, Austria, pp. 1–3 (2012)
28. Onime, C., Uhomoibhi, J., Pietrosemoli, E.: An augmented virtuality based solar energy power calculator in electrical engineering. Int. J. Eng. Pedagogy **5**(1), 4–7 (2015)
29. Onime, C., Uhomoibhi, J., Radicella, S.: MARE: mobile augmented reality based experiments in science, technology and engineering. In: Restivo, M.T.R., Cardoso, A., Lopez, A.M. (eds.) Online Experimentation: Emerging Technologies and IoT, pp. 209–227. IFSA Publishing, Barcelona (2015)
30. Onime, C., Uhomoibhi, J., Wang, H.: Mixed reality cubicles and cave automatic virtual environment. In: The 15th International Conference on Ubiquitous Computing and Communications (IUCC 2016), Grenada, Spain, pp. 1–8. IEEE Conference Publishing Services, December 2016
31. Onime, C., Uhomoibhi, J., Zennaro, M.: A low cost implementation of an existing hands-on laboratory experiment in electronic engineering. Int. J. Eng. Pedagogy **4**(4), 1–3 (2014)
32. Pastoor, S., Conomis, C.: Mixed Reality Displays. Wiley, New York (2006). pp. 261–280
33. Schwald, B., de Laval, B.: An augmented reality system for training and assistance to maintenance in the industrial context. In: Proceedings of International Conference on Computer Graphics, Visualization, Computer Vision, pp. 425–432. IEEE Computer Society (2003)
34. Takemata, K., Nakamura, S., Minamide, A.: Design of a lifelong learning program with regional collaboration: intership for high school students. In: Aung, W., Ilic, V., Moscinski, J., Uhomoibhi, J. (eds.) Innovations 2011: World Innovations in Engineering Education and Research, pp. 3–11. iNEER, Potomac (2011)
35. Zacharia, Z.C., Olympiou, G., Papaevripidou, M.: Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. J. Res. Sci. Teach. **45**(9), 1021–1035 (2008)

# Interactive Games as Educative Strategy to Motivate Students to Communicate Inside the Classroom

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**Abstract.** In the past years, English has been taught using the traditional methods and techniques, which has evoked low academic results in students' performance in listening and speaking subject; thus, this study has been carried out with the aim to increase students' motivation and participation inside the classroom through the use of interactive games based on deepening communicative skills. To conduct this study, a sample of one hundred students, who were randomly divided into two groups, the experimental and the control group as well as three English teachers of Universidad Técnica Particular de Loja (UTPL) participated in this study. The experimental and descriptive methods were employed to develop this research and a pre-test, an observation sheet, and a post-test were used as main instruments, which permitted to obtain information about the students' progress in the listening and speaking classroom. The most important finding confirmed the fact that the use of interactive games is very productive since it allows students to increase interest and motivation in order to obtain better learning outcomes and raise students' confidence at communicating in English.

**Keywords:** Classroom · Communicative skills · Educative strategy
Interactive games · Motivation

## 1 Introduction

English as a world language is used in different fields including education. In general, listening comprehension is essential in the way that students need to understand native speaking or any multimedia as well to receive language input [1]. With regard to speaking, [2] states that its development is crucial while learning a foreign language as it is a basic skill for communication. Thus, to enhance listening and to orally communicate in English, it is indispensable to concentrate on deep improvement of both skills [3], in order to become more familiar with English idiomatic expressions and collocations.

Regarding the situation in Ecuador, English as a foreign language (EFL) students have been facing difficulties in learning English, particularly by producing communication due to lack of confidence to speak, because most of the lessons are mainly based on development of reading and grammar than on speaking skills [4]. Furthermore, the use of traditional methods for teaching English, the low English teachers' level, and lack


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of pedagogical skills as well as no possibility to practise listening and speaking skills outside the classroom, unfortunately have a negative influence on students' learning progress and their academic results.

For that reason, some adequate and productive educative strategies such as the use of games must be proposed to motivate students to learn English and to participate more actively in the classrooms, which has turned into an essential topic that needs to be researched. Regarding this issue many studies have been conducted; for example, [5] as well as [6] based their researches on vocabulary games with the aim to show that games are used as a potential tool for enhancing and retaining vocabulary. Another study was the one carried out by [7], whose aim was to find out how the use of ubiquitous games in learning and teaching English influence English learning achievement and motivation. Additionally, [8] provided an explanation of how beneficial the use of games in English teaching can be. However, none of the aforementioned studies deal with the real problem of very low students' motivation to perform orally; hence, this study tries to search for interactive games based on communicative skills and students' creativity that will inspire and help them to produce speech and perform better in English.

## 2 Literature Review

### 2.1 The Use of Games to Improve Listening and Speaking Skills

Games encourage learners to sustain their interest and obtain better academic results in the EFL classroom; this is corroborated by [8], who claims that games have a positive and effective impact on the process of learning of a foreign language. In addition, [9] indicate that games are often used in the classroom for developing and reinforcing concepts, adding interest to the regular activities, and even for breaking the ice. [10, 11] goes further when he states that games provide the opportunity to practice communication skills. In this concern, [12] mention that when acquiring a foreign language, the main aim of students is to maintain appropriate communicative skills. Communicative skills can be developed and improved through the use of games in the classroom; [13] affirms that games allow the unconscious practice of all four basic language skills. He also declares that games reduce learner's anxiety to speak in front of their classmates because they feel less intimidated.

[14] argue that games build an atmosphere of significant communication where learners communicate before, during, and after applying them, which makes the language learning increase. In this concern, [15] declared that not only teachers but also parents agreed that games serve as an example of development of critical thinking, communication and negotiation skills.

Furthermore, [16] affirms that "games encourage, entertain, teach, and promote fluency and communicative skills"; hence, games deserve to be employed as an educative strategy in the EFL classes.

### 2.2 Classification of Games

There are different kinds of games that can be applied in classrooms depending on the target of the lesson, the learning outcome, the number of students, their age and interest, the space in the classroom, the students' cultural background, and the skill to be performed. [17] classifies them as follows: games for dividing larger groups into smaller ones, introduction, group, physical, scavenger hunt, educational, theoretical expression, drawing and coloring, educational card, word, story, and question games.

In addition, [18] came up with a different classification of games such as linguistic games focused on accuracy and communicative games, which are based on successful exchange of information such as: sorting, ordering, or arranging games, information gap, guessing, search, matching, labelling, exchanging, board games, and role play games/dramas; these games can be also competitive and cooperative in which students want to win the race by working together in order to achieve a common goal.

Similarly, [19] categorize games in movement, dice, singing and chanting games. They also argue that games are dissimilar to the rest of activities employed in the English learning because of the set of rules, which serve as a strategy to guide students' procedure.

### 2.3 Interactive Communication Games

Using interactive games is a powerful language-learning tool for students as learners use the target language to defend themselves to persuade and negotiate, so that they can achieve the desired results while productive and receptive skills are involved at the same time. Furthermore, language teachers are required to promote task-oriented activities that engage students to be more creative as well as games to develop students' communicative skills [20].

Interactive communication games activities play an important role for listening and oral practicing as well as for acquiring and increasing vocabulary input and output. Interactive communication games have different purposes such as giving directions or asking questions, while others support a team work and create communication to solve a problem [10, 11].

## 3 Method

### 3.1 Participants

In this study participated 100 beginner and intermediate Ecuadorian university students enrolled in a Listening and Speaking subject, whose ages ranged from 18 to 25 years old and who have been learning English as a foreign language. In addition, three teachers took part in this study, whose role was to apply the games and evaluate students' progress in communicative skills during the research period.

### 3.2 Procedures

The first step to carry out this study was to identify students' English level through an oral diagnostic test. The experimental and descriptive methods were applied to obtain and interpret the data, as well as the qualitative method was used to analyze the results gathered. The second step involved to employ the experimental method, where students were randomly divided into the experimental and the control group; each group consisted of a sample of 50 participants. Students in the experimental group were taught English with the use of interactive games as a strategy for motivation with the aim of acquiring new vocabulary to produce oral speech, while the control group followed the traditional teaching method using the main textbook activities.

The principal instrument was an observation sheet, which permitted to take notes of the impact of games on students' learning process. The research took eight weeks and various games based on the contents of the textbook and the students' level were selected considering the Hadfield games taxonomy.

At the end, a final oral evaluation was administered to verify the students' progress.

## 4 Analysis of Results

To achieve the objectives of this study, several activities for both groups were planned and applied in the EFL classes, obtain the desired results. The activities presented in each group are indicated in Table 1.

**Table 1.** Course design

| Phase | Control group | Experimental group |
|---|---|---|
| Diagnostic test (Week one) | The teacher applied a diagnostic test and explained the activities that were taught during the set up period | The teacher applied a diagnostic test and explained the activities that were taught during the set up period |
| Something valuable (Week two) | The students worked on listening and speaking activities by identifying the main ideas and supporting details about the topic using tracks from the CD provided in the textbook. At the end of the class, teacher administered test 1 | Teacher applied the memory game and at the end of the class teacher administered test 1 |
| Together is better (Week three) | Students listened to a dialogue. Later, they worked on activities from the textbook; teachers administered test 2 | Students played a guessing game to identify and reinforce vocabulary; teachers administered test 2 |
| Thinking young, creativity in business (Week four) | Students watched and listened to a video about a business magazine and answered the questions proposed in the textbook; teachers administered test 3 | Students played a barrier game to listen to instructions and react to them showing their comprehension and leading skills; teachers administered test 3 |
| Planting trees for peace (Week five) | Students worked with pictures presented in the textbook in order to find similarities and differences about planting or not planting trees; teachers administered test 4 | Students played a guessing game to recognize vocabulary based on using the smell sense of specific plants related to the topic; teachers administered test 4 |
| Driving you crazy (Week six) | Students worked on a matching activity and practised speaking using the vocabulary from the unit; teachers administered test 5 | Students played a bingo game to infer the meaning from pictures and their definitions; teachers administered test 5 |
| Only child, lonely child (Week seven) | Students expressed opinions of agreement and disagreement related to questions from the textbook; teachers administered test 6 | Students were involved in a role play game by creating a story; teachers administered test 6 |
| Evaluation (Week eight) | Teacher administered a post-test | Teacher administered a post-test |

The results of the diagnostic test, which are shown in Table 2, demonstrated that most of the students did not have enough knowledge of English vocabulary to communicate in the target language. Only a few students showed to have an excellent level due to their prior knowledge and skills on the language gained from attending classes in private English institutions.

**Table 2.** Results of diagnostic test

| Category | Experimental group | Control group |
|---|---|---|
| Excellent | 8 | 7 |
| Good | 12 | 13 |
| Fair | 18 | 19 |
| Poor | 12 | 11 |
| **TOTAL** | **50** | **50** |

At the end of this study students took a post-test to confirm the effectiveness of using games in the experimental group; these results are presented in Table 3.

**Table 3.** Results of post test

| Category | Experimental group | Control group |
|---|---|---|
| Excellent | 14 | 9 |
| Good | 20 | 15 |
| Fair | 9 | 16 |
| Poor | 7 | 10 |
| **TOTAL** | **50** | **50** |

It is clear that by applying games students from the experimental group could improve their English level in listening and speaking skills; also they enriched their vocabulary as well as their pronunciation was improved significantly. In addition, students were willing to compete, which demonstrated their enthusiasm towards games and motivation to play them and take risks in language practice [14].

It was also encountered that interaction between students-teacher, students-students was greatly deepened as games permitted more engagement and positive classroom environment [21]. Furthermore, it was noticed that students gained more confidence in producing spontaneous speech and their ideas were expressed in the target language easily and naturally, and anxiety was also reduced [22].

On contrary, the control group showed different results regarding the acquisition of vocabulary, which was limited to exercises from the textbook and there was not a big range of activities that would involve students' interaction.

### 4.1 Games Applied in the Experimental Group to Develop Listening and Speaking Skills

In this research, Hadfield games taxonomy was adapted to focus on developing speaking skills. The main categories employed were memory, guessing, barrier, bingo and role play games. Clear instructions of each game are provided below.

The first game was based on memorizing with the aim of supporting opinions using new vocabulary. The teacher demonstrated some real world objects related to valuable articles such as a credit card, a photo, a piece of jewelry, a cell phone, a coin, a book among others, and asked students to name each object. After that, students repeated the correct pronunciation of the words. Then the objects were hidden and students had to remember their names and write them on a piece of paper. Later, students opined with supporting details on the most valuable thing that they possess in their lives. As a result, this game permitted to enhance vocabulary and to increase critical thinking [18].

The second activity was focused on guessing game with the objectives of identifying and reinforcing vocabulary, interpreting and describing a picture. The teacher divided the class into 5 groups of 10 students and in each group a picture was shown for a minute. Later, the teacher made questions related to the picture that helped students discover the topic. The rest of the class was dedicated to reinforcement of vocabulary by applying a guessing game, which consisted of 25 pictures. The pictures were placed upside down in a circle, so that students could not see what the pictures and words were about. In the middle of the circle, it was located an arrow that allowed a movement of left or right with a number (1–3) to move on to get a turn. Once students guessed correctly, they had to tell a sentence using the picture word. This game allowed to reinforce vocabulary and to use it in sentences in a simple way.

Barrier game was used to show leading skills providing clear instructions. The teacher divided students into 25 pairs that were sitting back-to-back. Each student had to draw any picture for about 2–3 min. Then every learner from the pair was given instructions how to draw the same picture as his/her classmate had done before. Next, the pictures were compared to find differences or similarities and point out, how well the instructions of each student were provided and how well students understood. To sum up, students could develop their listening and improve speaking skills by giving instructions. It also permitted teacher to review the grammar.

Guessing game aimed to recognize vocabulary based on using smell sense of specific plants related to the topic. The teacher divided class into 5 groups of 10 students. Each group had a leader who covered student's eyes with a scarf and presented them a sample of plants and they had to guess their names according to their smell. At the end, the teacher showed all plants and named all of them. In that way vocabulary was reinforced. After that, students watched a short video about planting trees and each student had to fill in a worksheet with phrases that referred to expressing of opinion. These phrases were practised, so that students became confident to express themselves easily. Furthermore, they could identify the proposed objectives, which enabled them to deepen their vocabulary.

Bingo game was used to infer the meaning from pictures and text related to transport signals. Students participated in matching vocabulary activity. Then, the teacher played "bingo", in which students practised the vocabulary. This vocabulary was later used to interpret and produce speech "How to drive safely". Bingo allowed students to be competitive and permitted them to create a positive and enjoyable learning environment.

The last game was the very well-known role play, that enabled students to organize the information and create a story. Students were divided into 5 groups of 10 members and were given pictures of movies to create a story within 5 min. Once the story was presented, teacher played the trailer of the movie that lasted 2 min, and asked them to identify the similarities and differences between their own play and the real ones. This game allowed to show students' creativity.

## 5 Conclusions and Impact of Games in Students' Learning of a Foreign Language

Throughout the observation active students' engagement and use of English were noticed. They exposed an enormous attention by their individual participation in each game; they also showed a deep interaction among other students as well as among teachers and students.

It was also found out that games motivate students a lot and help them obtain better learning outcomes; acquisition of vocabulary was greatly improved; they even became more confident at expressing their opinions.

It is also worth mentioning that the games applied can be suitable for beginners and pre-intermediate levels of teenager or adult groups. They can be employed individually, in pairs or in groups.

The research showed that experimental group achieved better academic results in comparison to the control group. It was due to the fact that students felt enthusiastic about making a big effort to win in each game. Even the post evaluation confirmed that students reached the desired higher English level in speaking. Finally, it can be said that interactive communication games present a different learning strategy to be employed in the classroom to gain the students' interest and create a positive, relaxing and enjoyable teaching-learning environment.

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## References

1. Gilakjani, A., Sabouri, N.: The significance of listening comprehension in English language teaching. Theor. Pract. Lang. Stud. **6**(8), 1670–1677 (2016)
2. Oradee, T.: Developing speaking skills using three communicative activities (discussion, problem-solving, and role-playing). Int. J. Soc. Sci. Humanity **2**(6), 533–535 (2012)
3. Ferris, D., Tagg, T.: Academic listening/speaking tasks for ESL students: problems, suggestions, and implications. Tesol Q. **30**(2), 297–320 (1996)

4. Council, B.: English in Ecuador: An examination of policy, perceptions and influencing factors (2015). https://ei.britishcouncil.org/sites/default/files/latin-america-research/English%20in%20Ecuador.pdf
5. Yip, F.W., Kwan, A.C.: Online vocabulary games as a tool for teaching and learning English vocabulary. Educ. Media Int. **43**(3), 233–249 (2006)
6. Guillén-Nieto, V., Aleson-Carbonell, M.: Serious games and learning effectiveness: the case of It's a Deal! Comput. Educ. **58**(1), 435–448 (2012)
7. Liu, T.Y., Chu, Y.L.: Using ubiquitous games in an English listening and speaking course: impact on learning outcomes and motivation. Comput. Educ. **55**(2), 630–643 (2010)
8. Frydrychova-Klimova, B.: Games in the teaching of English. Procedia Soc. Behav. Sci. **191**, 1157–1160 (2015)
9. Herrel, A., Jordan, M.: 50 Strategies for Teaching English Language Learners. Florida State University, Pearson (2016)
10. Richard-Amato, P.: Making It Happen. Longman, White plains (1996)
11. Clerk Maxwell, J.: A Treatise on Electricity and Magnetism, vol. 2, 3rd edn. Clarendon, Oxford (1892). pp. 68–73
12. González, P., et al.: EFL teaching in the amazon region of ecuador: a focus on activities and resources for teaching listening and speaking skills English. Lang. Teach. **8**, 1916–4750 (2015)
13. Chen, I.J.: Using games to promote communicative kills in language learning. Internet TESL J. **11**(2) (2005)
14. Wright, A., Betteridge, D., Buckby, M.: Games for Language Learning, Cambridge Handbook for Language Teachers, 3rd edn. CUP, Cambridge (2006)
15. McFarlane, A., Sparrowhawk, A., Heald, Y.: Report on the educational use of games. TEEM (Teachers Evaluating Educational Multimedia) (2002). www.teem.org.uk
16. Uberman, A.: The use of games for vocabulary presentation and revision. English Teach. Forum **36**(1), 20–27 (1998)
17. Dögg Sigurðardóttir, S.: The Use of Games in the Language Classroom (Tesis inèdita). Universidad de Islandia, Islandia (2010)
18. Hadfield, J.: Intermediate Vocabulary Games. Longman, Harlow, Essex (1999)
19. Lewis, G., Bedson, G.: Games for Children. OUP, Oxford (1999)
20. Saricoban, A., Metin, E.: Songs, verse and games for teaching Grammar. Internet TESL J. **6**(10) (2000). http://iteslj.org/Techniques/Saricoban-Songs.html
21. Tsiplakides, I., Keramida, A.: Helping students overcome foreign language speaking anxiety in the English classroom: Theoretical issues and practical recommendations. Int. Educ. Stud. **2**(4), 39–43 (2009)
22. Horwitz, E.K., Horwitz, M.B., Cope, J.A.: Foreign language classroom anxiety. Mod. Lang. J. **70**(2), 125–132 (1986)

# Communicative Style: Act Like a Pro

## How Authenticity Management Can Support Students in Communicating Effectively in a Second Language

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**Abstract.** The present teaching case looks at how a social constructivist approach to language teaching can support students of industrial engineering in developing an effective communicative behavior which allows them to demonstrate authenticity in their second language. A specifically designed methodology mix of blended learning activities, including role play, poetry reading and reflective writing tasks, encourages students to step out of their comfort zone and adopt a playful and proactive attitude towards reaching their communicative goals in different social and corporate settings. Like this, students start to realize that exhibiting effective communicative behavior is a choice which requires an excellent command of the foreign language and the ability to decide which facet of one's personality is best to be revealed to whom and in which moment.

**Keywords:** Social constructivist teaching approach
Second language acquisition · Peer learning · Authenticity management · Role play
Poetry · Reflective writing · Blended learning · Effective communication

## 1 Introduction

### 1.1 Industrial Engineers Need to Be Effective Communicators

Successful industrial engineers need to excel in a wide range of professional settings, including manufacturing, logistics, quality control, energy systems, transportation, and controlling. They need to apply innovative thinking and be able to manage teams and places as well as information. Industrial engineers who want to have real influence on a global scale need to be effective communicators who are able to connect with team members, decision-makers, investors and politicians in their second language. Exhibiting an effective communicative behavior in settings where people do not share the same cultural norms and have different expectations for how they should behave does not only ask for advanced foreign language skills, but for overall communication competence, including emotional intelligence, cross-cultural understanding, and last but not least the ability to quickly adapt one's communicative behavior to different contexts while at the same time preserving one's distinctiveness and demonstrating authenticity.


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### 1.2 Hypothesis of the Present Teaching Case

The present teaching case investigates how industrial engineering students from Austria, Bosnia and China can best be supported in developing an effective communicative style in their second language - English. It is based on the hypothesis that non-native speakers of English who learn how they can manage authenticity in their second language are more likely to reach their communicative goals than non-native speakers of English who are trained to focus on the correct application of grammar and jargon only. To verify this hypothesis, a student-centered, social-constructivist approach to language teaching and a specifically designed methodology mix of social and introspective learning activities is applied. The teacher takes the role of facilitator who encourages students to step out of their comfort zone and explore the impact of different communicative behaviors in different contexts.

### 1.3 The Context of the Present Teaching Case

The present teaching case is embedded in an English language class for $4^{th}$ semester bachelor students of industrial engineering at the University of Applied Sciences (CUAS) in Villach (Austria). Most students have a regular job and do their bachelor studies in the evenings and on weekends. They are aged between 22 and 38 years and come from different regions in Austria, Bosnia and China. They attend English lessons over a period of 5 semesters. Depending on their cultural background and previous language education, their level of English is B1 to B2, according to the European Framework of Reference for Languages. The class is sub-divided into two groups of 12 and 13 students and each semester focuses on a special learning goal. The specific teaching goal for the $4^{th}$ semester is to improve proposal writing skills and to create awareness among students that effective communicative behavior requires excellent language skills and overall communication competence, including emotional intelligence, cross-cultural understanding, and authenticity management. Students need a lot of guidance, at the same time they need to be encouraged to take responsibility for their learning.

### 1.4 Definition of Authenticity Management

Authenticity plays an important role when it comes to achieving one’s communicative goals. That, among other things, may explain why in recent years, authenticity has been more and more in demand in the context of business and politics, as well as in leadership trainings, as referred to in [8]. But how exactly do we define authenticity? Some people think that the term “is often used in a misleading way and has been thought of as the opposite of artifice – something that is straightforward, sincere, and uncomplicated”, as stated in [9]. And that “this conception of authenticity is simplistic, even wrong-headed.” As a matter of fact, the debate over what it means to be authentic has become increasingly complex and embraces research from a wide variety of fields, including discourse and conversational analysis, pragmatics, cross-cultural studies, sociolinguistics, second language acquisition, cognitive and social psychology, learner autonomy, ICT, motivation research and materials development. “The fact that English is spoken by 80% non-native speakers has further complicated the concept of authenticity, which can be situated in the learners themselves, in the social or cultural situation and purposes of the communicative act, or some combination of these”, as stated in [10].

The present teaching case places authenticity within the framework of international business situations where it is very likely that non-native speakers of English communicate with each other. Authenticity management is therefore defined as the *ability to adapt one’s communicative behavior to different contexts in a second language while staying connected with and communicating a core self*. This definition requires effective communicators to have a good command of the foreign language and to be acquainted with the different facets of their personality so that they can decide which facet of their authentic self they want to reveal to whom and in which moment.

## 2 Research Approach

### 2.1 Social-Constructivist Approach to Language Teaching

Encouraging bachelor students of industrial engineering to explore the different facets of their personality and learn to manage authenticity in the framework of an English language class is an ambitious endeavor. It implies that students realize that communicating effectively in a second language does not just mean using the appropriate technical vocabulary and applying grammar correctly but asks for a high level of cross-cultural awareness, strong emotional intelligence, excellent listening skills and last but not least the ability to demonstrate real authenticity in the foreign language. To verify the hypothesis of the present teaching case and to provide students with a deep learning experience, a student-centered, social-constructivist teaching approach was applied where the teacher takes the role of language guide and facilitator rather than instructor. Vygotsky’s peer learning concept [11] and notion of the zone of proximal development (ZPD), according to which learning only takes place when learners need to accomplish tasks that challenge them just beyond their level of competence and therefore can only be achieved with the support from the teacher and more advanced peers, served as inspiration. Also, Wenger’s concept of communities of practice [12] and its focus on social and situated learning played an important role when creating an experiential learning environment within which students could improve their *practice*, i.e., developing an effective communicative style in their second language. A specifically designed methodology mix of blended learning activities, including role play, improvisation theater activities, poetry readings, profound video analyses and aligned reflective writing tasks were applied. The online writing assignments included tailor-made feedback on students’ linguistic (grammar and mechanics), socio-linguistic (style and tone), and pragmatic (context and meaning) competencies. Moodle, Google docs and the online writing environment Basecamp served as online learning management system.

### 2.2 Methodology Mix and Impact Measurement

Developing an effective communicative behavior in one's second language and the ability to manage authenticity does not happen over night. Rather, it is a long-term learning process that starts with awareness-building. Accordingly, one semester, which covers 4 months and 30 units of English, is too short to carry out any substantial quantitative measurements. However, qualitative data were gained from students' feedback, video analysis and observation and allowed to draw some conclusions on the impact of individual learning activities.

A specifically designed methodology mix of social and introspective learning activities, including pitch presentations, discussion leads, role plays, poetry readings and reflective writing tasks was applied in a student-centered, social-constructivist learning environment. Students were filmed and familiarized with useful linguistic tools in order to be able to analyze their communicative behavior and learning progress. A constructive feedback culture was established with a focus on content, body language, tone of voice, language register, choice of words and cross-cultural aspects of communication. In detailed feedback sessions, students were invited to openly share their thoughts and insights with their peers. To internalize the learning experience, they had to reflect on their actual and ideal communicative behavior in writing.

### 2.3 Role Play

Specifically designed simulations of real life settings were used to help students acquire the ability to adapt their communicative behavior to different contexts while staying connected with a core self. A bit like in acting classes, students needed to get familiar with their role and anticipate what the other players would need and expect from them. To demonstrate authenticity, they were encouraged to act out "the bits of their personality that were relevant for the specific situation", as explained in [13]. A two-step process forced them to leave their comfort zone: First, roles were allocated in a way that matched students' personalities, which made it rather easy for them to identify with their role and concentrate on language issues; in a second step, students were given more challenging roles where they had to act counter to their personal preferences. Here, the challenge was two-fold: on the one hand, students had to identify with a role that did not suit their personal preference and on the other hand, they had to choose the appropriate language register, make the right choice of words, and apply a proper tone of voice to win acceptance in the given situation. A detailed video analysis followed each role play sequence.

### 2.4 Reflective Writing Practice

In between the face to face units students were asked to reflect on their communicative performance in writing. Students had to deliver their writing assignments through an online writing environment and received tailored feedback on grammar and mechanics (linguistic competency), style and tone (sociolinguistic competency), and context and meaning (pragmatic competency) of their writing. The online environment served students as a kind of learning journal where they could interact with the teacher, ask questions, and make notes. Also, their learning progress was measured in the above categories and students could see their progress in writing according to the European Framework of Reference for Languages.

## 2.5 Unexpected Learning Activities: Poetry Reading

Students felt particularly challenged by a number of unexpected learning activities, including poetry readings and thought games. For example, two students per group were asked to recite a specifically chosen poem with a special tone of voice in front of the audience and a camera. Students then had to explore the different layers of the poem and create new thinking space (Fig. 1).

**Magician, by Love Alice for TalkShop.cc ©**

I know someone,
He collects jars,
Inside these jars,
Are my memories.

He is mainly there,
When I am alone,
Sometimes, I am sad
And he takes my sadness
And locks it in a jar.

Once I was crying,
And he drew a handkerchief,
On a piece of paper.
My tears dripped,
Like drops of rain,
On his drawing.
I thought he will be mad,
Instead,
He smiled at me
And blew on the paper.
That's all it took,
For a rainbow to appear,
I forgot my sadness,
But he did not forget
To seal the jar.

I know someone,
He collects jars,
Inside these jars,
Are my memories.

He is mainly there,
When I am alone,
Sometimes, I am happy
He takes my joy,
And locks it in a jar.

Once I was laughing so hard,
My belly was hurting,
He asked me to laugh
On a golden cup,
The sound was like music!
I did it again and again
Until I ran out of laughter!
He took the golden cup
And sealed the jar.

I know someone,
He collects jars,
Inside these jars,
Are my memories.

I see him once in a while now,
Most of the meetings,
I am full of questions.
I ask him why,
My tears fall from my eyes?
I ask him why,
My mouth widens,
At the sight of a rainbow?
I ask him why,
I love thunders?

No answer.
He has none.
But he gave me jars,
Once I opened them,
He never returned again.

**Fig. 1.** Poem by Love Alice (aka Lovelyn Andrade) chosen for a poetry reading session with industrial engineering students to activate their thinking skills. Students associations were wide-ranging and interesting, they felt inspired to create new thinking space.

# 3 Lessons Learned

## 3.1 Role Play Creates Awareness for Authenticity Management

Developing effective communicative behavior and demonstrating real authenticity in a second language is certainly a long-term process. As pointed out earlier, only qualitative results can be shared after 4 months. Overall, it can be said that students have developed an idea of what effective communicative style could mean for them personally and which skills it requires. By exploring different roles – from visionary to investor, researcher, chairperson, student, university professor, subject matter expert, innovator, entrepreneur, consultant and influencer – and experiencing the consequences of effective as well as ineffective communicative behaviors, students could find out how tone of voice, language register, empathy and other relevant communication skills could support them in establishing their authentic self in the second language.

## 3.2 Language Proficiency Is not Enough to Manage Authenticity

Naturally, students who had a good command of the English language found it easier to identify with their role, even if it did not fit their personal preference. The video analysis showed that they felt comfortable and confident in the situation. Students who were struggling with their language skills had more difficulty to focus on their communicative goal: they chose the wrong language register, lacked vocabulary, made grammar mistakes, felt too shy to clarify misunderstandings or simply remained silent. Their body language revealed that they felt uncomfortable in the situation. Given all the pressure, they did not manage to communicate authentically and were not satisfied with their performance. What is more, students who struggled with the language tended to act and communicate on the basis of their personal preferences, assumptions and experiences rather than adapt their communicative behavior to the specific context.

Interestingly, students who had a good command of the English language but felt they were "playing a role", did not manage to get their message across. They were not able to identify with their role and even started criticizing the instructions for not being clear or challenging enough.

It can be concluded that communicators with good language skills are generally more successful when it comes to adapting their communicative behavior to a specific context. However, the ability to demonstrate authenticity in a second language does not only depend on language proficiency but on a communicator's ability to connect with a facet of their personality that they could channel to their specific role in a given situation. Students who were able to connect with a facet of their personality but were struggling with the language, had almost no chance to make their voice heard. For example, a female Chinese student wrote in her reflective writing assignment that she would love to contribute a lot more in class but that the language barrier was simply too high. Chinese students who had a good enough command of the English language and were able to connect with and communicate a core self were perceived as self-confident players who managed to build rapport with the others.

### 3.3 Peer Learning and Feedback Culture Allow for Deep Learning

Focusing on their practice, i.e., developing an effective communicative style and demonstrating real authenticity in the second language, clearly helped students develop trust and mutual respect for each other. When it comes to giving feedback, they were generally a bit shy in the beginning but got used to the process after a while and started giving critical feedback in a very constructive way. In a first step, they had to give each other feedback on body language, tone of voice, content, and overall communication skills. In a second step, they were encouraged to tell their peers what was unique, authentic and effective about their communicative behavior. Having established a good feedback culture, students encouraged each other to try out new things in their face to face sessions. The role of the teacher clearly was to support students in developing a constructive feedback culture as well as to add important nuances and ask questions that further stimulated the learning.

### 3.4 Students Take Responsibility for Their Learning

It is difficult to bring a real world language experience into the classroom and infect students with the love for learning. When it comes to second language acquisition, one of the most important things is to make learners stop thinking that the foreign language is "an epiphenomenon of their own language and that it refers to and embodies their existing understandings and interpretations of their own and the foreign cultures" [13]. The present teaching case has shown that a blended mix of social and introspective learning activities encourage students to take responsibility for their learning and create new thinking space in order to gain a new level of understanding with regard to effective communicative style. During the semester – and it has to be pointed out here that previous semesters had already prepared students for this type of social language learning activities – students clearly developed a bigger interest in each others' points of view and cultural backgrounds. Again, the role of the teacher is to foster a peer learning culture which is based on a social-constructivist approach and which promotes collective and individual learning.

### 3.5 Poetry Reading Helps Students Build Emotional Capacity

According to neuroscientist Antonio Damasio, the idea that we are "rational creatures", which goes back to Descartes, and that we best make decisions by applying logic, is not helpful when it comes to making decisions and pursuing one's communicative goals [14]. His findings have shown that emotional capacity plays an increasingly important role in today's business world, in addition to logic and deductive reasoning. Industrial engineers who want to act as enablers on a global scale need to build emotional capacity, which is part of decision-making and communication competence. It can be concluded that especially the activity of reading and interpreting poetry in class encouraged students to explore new avenues of thinking and build emotional capacity. "A poem is a distillation of thought, experience and emotion into a tightly controlled form that utilizes words, images, sound and rhythm patterns to create a complex set of meanings", as is stated in [15]. Some students were more interested than others, some where a bit shy and insecure, but most of them took the activity very seriously and inspired each other with good associations and ideas. When choosing a poem for such a framework and purpose, the teacher needs to make sure that the poem is accessible, language wise, and at the same time offers enough layers so that participants can discover and create new thinking space. And of course the poem has to be beautiful, rhythm-wise and also with regard to the images it conveys.

### 3.6 Students Develop Social Antennae

The various learning experiences outside their comfort zone sharpened the communicative awareness of students. Especially the role play and poetry reading activities encouraged them to display different parts of their true self and develop stronger emotional intelligence. Like this, students started developing a sense for appropriate communicative behaviors in situations they may encounter in real life: a pitching situation, a team meeting, a conference setting, a discussion round setting and some others. It was definitely interesting to see how students automatically conformed to cultural stereotypes or were trapped in their own cultural framework. For example, the role of investor was associated with the communicative behavior of an arrogant person who spoke with an American accent. At the same time, the role of university professor stirred a shy and somewhat uncomfortable feeling in students as they were lower in hierarchy in real life. When discussing and reflecting their communicative behaviors, students were asked to come up with more effective alternatives.

### 3.7 Effective Communicative Style Is a Choice

Students clearly have realized that successful communication in a second language is based on the ability to strike a balance between language proficiency, cultural norms, social expectations, and the ability to manage authenticity. They started to better understand the power of language register, tone of voice, and body language. Also, they have become aware that exhibiting effective communicative style is a choice they need to make, a skill they can learn and train. It was definitely important for students to see how the ability to manage authenticity and adapt their communicative behavior to different contexts in the second language could support them in pursuing their communicative goals and win acceptance in different cultures and settings.

## 4 Conclusions and Outlook

### 4.1 Step 1: Building Awareness

It goes without saying that developing an effective communicative behavior in a second language is a complex, long-term learning process that requires a lot of practice and discipline. The present teaching case has demonstrated that a social-constructivist approach to language teaching and a learning environment that is based on peer learning, mutual respect, trust and continuous reflection can empower students to step out of their comfort zone and explore different communicative behaviors. By accepting and showing their vulnerability, students can start removing some of their communicative barriers in the second language, which is an important step when it comes to pursuing one's communicative goals.

Most students were not aware of their communicative appearance in the beginning. Especially the role play activities and subsequent video analysis helped them to develop a better understanding of the impact of their communicative behavior and how they can make use of language register, word choice, effective body language and tone of voice to demonstrate real authenticity in their second language.

What is more, students have become acquainted with different and new facets of their personality and slowly started – or at least started thinking about – harnessing those. What is important here is that students were not told or asked to adapt their personality to a specific context, but to decide which facet of their personality they wanted to disclose to whom in which moment to demonstrate authenticity. Like this, students could become aware that their communicative behavior is an active choice they make and that body language, tone of voice, and language register are important aspects of that choice. After all, "55% of our communication are believed to go through body language and 38% through tone of voice", as is stated in [16].

## 4.2 Step 2: Managing Authenticity

Some might argue that channeling part of one's self to a specific role is manipulative and prevents communicators from demonstrating real authenticity. The author of this paper thinks that as long as we do not lose our core self, managing authenticity or the ability to decide which facet of our personality we want to reveal in a specific context can be a useful technique that helps communicators win acceptance in different settings in a second language. Adopting a proactive and playful but still professional attitude towards making one's voice heard can help non-native speakers exhibit effective communicative behaviors in their second language. What is more, this approach towards language learning helps students create new perspectives and build a bridge to their communicative challenges in real life. "After all, successful communication depends on much more than a (superficial) command of a target language, it requires the ability to see the world from different perspectives", as is pointed out in [13]. At the end of the semester, most students confirmed that they felt a lot more confident when communicating in their second language and that they had less fear of acting out bits of their personality (in front of a camera). They also said that they had not only developed an idea of their ideal communicative style and discovered some new attributes in themselves, but that they had also learned to value each others' contributions and better understand different cultural norms, expectations and behaviors.

To sum up, the present teaching case has demonstrated that a social-constructivist approach to language teaching, which focuses on the development of overall communication competence and the ability to manage authenticity, can support learners in becoming effective communicators in their second language. The teacher's role is clearly that of a facilitator who needs to infect students with the love for learning and encourage them to continually re-write their learning narrative by challenging them with always new, challenging and useful learning activities.

### 4.3 Outlook

Language classes (for industrial engineering students) can open up new avenues and provide experiential spaces where students can try out new things that will help them develop their overall communicative competence. The approach presented in this paper has also been tested in several other academic and corporate settings and provided similar results. As a next step, it would be interesting to focus more on the consequences of appropriate and inappropriate communicative behaviors in different contexts and to include more elements of acting and improvisation theater as well as to use more tailor-made video material and apply digitally designed role plays. Further, it would be interesting to integrate more real life experiences of learners. To further expand and refine the teaching format, more qualitative and then also quantitative measurements of impact will be needed. For this, it will be necessary to implement the approach on a larger scale, compare different groups of learners over a longer period of time, and have students regularly take tests that are specifically designed to measure the various competencies acquired, including emotional intelligence, intercultural competence and authenticity management competence. A special focus also needs to be put on the development of authentic teaching materials and learning activities in support of this teaching approach.

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## References

1. Bandura, A.: Social Learning Theory. General Learning Press, New York (1977)
2. Kolodziej, L.: Model-directed Learning. Albert Bandura's Social Cognitive Learning Theory and Its Social-Psychological Significance for School and Instruction (2006). ISBN 978-3-656-88129-2
3. Johnstone, K.: Improvisation and the Theater. Methuen Drama, London (2007). ISBN 10: 0713687010
4. Hall, P., Simeral, A.: Teach, Reflect, Learn. ASCD, Alexandria (2015)
5. Strunk, W., White, E.B.: The Elements of Style. Pearson Education (2000)
6. Callahan, S.: Putting Stories to Work. Pepperberg Press (2016)
7. Ibarra, H.: Working Identity: Unconventional Strategies for Reinventing Your Career. Harvard Business Review Press, Cambridge (2003)
8. Authentic Brands Study. Cohn and Wolfe (2014)

9. Goffee, R., Jones, G.: Managing Authenticity: The Paradox of Great Leadership. Spring (2017). HBR.org
10. Gilmore, A.: Language teaching: authentic materials and authenticity in foreign language learning, pp. 97–118 (2007)
11. Kozulin, A., Gindis, B., Ageyev, V., Miller, S.: Vygotsky's Educational Theory and Practice in Cultural Context. Cambridge University Press, Cambridge (2003)
12. Wenger, E., Lave, J.: Situated Learning: Legitimate Peripheral Participation (1991). ISBN 9780521423748
13. Ibarra, H.: Act Like a Leader, Think Like a Leader. Harvard Business Review Press (2015)
14. Damasio, A.R.: Descartes' Error: Emotion, Reason and the Human Brain. Penguin Books, London (2005). Reprint edition
15. Buswick, T., Morgan, C., Lange, K.: Poetry in the boardroom: thinking beyond the facts. J. Bus. Strategy **26**(1), 34–40 (2005)
16. Pease, A., Pease, B.: The Definitive Book of Body Language. Bantam (2006). ISBN 139780553804720

# Remote and Virtual Laboratories

# Work-in-Progress: A Smart Scheduling System for Shared Interactive Remote Laboratories

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**Abstract.** Online laboratories are an innovative solution for providing hands-on experience in the STEM Education. A large number of students are using remote laboratories (RL) to meet their practical needs and enriching their learning. The deployment of a unique instance of the RL cannot provide all requirements for the growing number of students. For that purpose, the use of multiple instances of RLs can produce many advantages. We propose in this paper a new method for managing access to these RLs. The implemented system provides a central point of control all requests to access to the RLs. This approach is transparent to the user. The system under development supplies an abstraction layer. The goal of the work is to build a web service through which the access to RLs is granted. The student will don't need to reserve a time slot to access the RL. In addition, the system supports the registration of new RLs in a transparent way for teachers.

**Keywords:** Remote laboratories · Smart scheduling · Web services · REST

## 1 Introduction

Online laboratories are modern techniques for providing hands-on experience in the STEM Education [1]. However, the effectiveness of the RL environment is largely dependent on the effectiveness and ability of its schedules. This component system mediates access to distributed RLs.

In an e-learning environment in which there is only one instance of the laboratory, a booking system is usually used [2–5]. However, this solution is not efficient if there are multiple instances of the laboratory. The increase of the number of resources generates a complexity of management and the system became less useful for the student.

This paper describes the design and implementation of as mart scheduling system requiring minimal human intervention and fully transparent for the student.


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## 2 Architecture of the Smart Scheduling System

The proposed architecture is an extension of the solution developed by Farah et al. [6]. A pcDuino [7] based Ethernet Flexible Hardware Interface (EFHI) allows multiple configuration of the Practical Evaluation Board (PEB). The student interface needs a set of Universal Resource Locator (URL): the EFHI URL and the URL of each instruments plugged in the practical evaluation board (PEB) in order to configure the circuit and perform measurement.

Figure 1 illustrates the remote laboratory in operation.

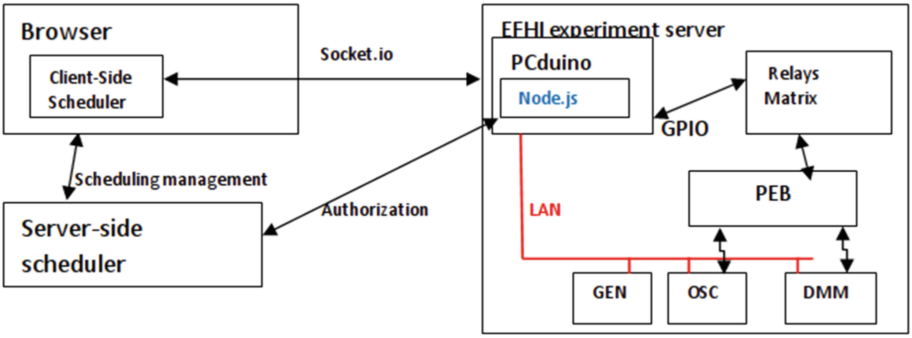


**Fig. 1.** The architecture of the proposed solution. EFHI adapted from [6]

To achieve sustainability and easy maintainability a service-oriented approach is used. The scheduling service is developed as a stand-alone external service, so that it can be reused in other RLs deployment. That system is split into two separate web services-based systems, the Client-side-Scheduling service and the Server-side Scheduling Service.

In the following section, we describe in detail the three services for the architecture: Server-side scheduler, Remote laboratories directory service and Client-side scheduler.

### 2.1 Server-Side Scheduler Service

The Server-Side Scheduler (SS-Sc) provides a central point of control to all access requests to the RLs. It supplies an abstraction layer that implements the necessary functions and enables load balancing between instances,

The Application Programming Interface (API) of the scheduler server maintains the RL status of all the connected remote laboratories. For each access request the scheduling service, check if the user is already authenticated, then consults the in-memory database for the status of the laboratories servers. Finally, it returns to the client the URLs of the free rig.

The server side scheduler API is organized around REST with JSON responses. The API is designed to use HTTP response codes to indicate API success/errors.

The Table 1 summarizes the endpoints to the Node.js server that implements the REST API.

**Table 1.** The scheduling API endpoints

| Route | Http verb | Description |
|---|---|---|
| /api/reservation/:id | GET | Get the render of the lab with id [id] that contains the iframe with src = urls list |
| /api/labs | GET | Get all labs for build the single page application |
| /api/lab/:id | GET | Get a singleton resource representing of the lab with id [id] or a 404 response |
| /api/duration/:id | GET | Get the session time of the lab with id [id] |
| /api/logout/:id | GET | Logout the id RL |
| /api/register/:_id | POST | Register a new EFHI experiment Server |
| /api/sync/:id | GET | Used to synchronize with the scheduler and keep the state of the platform busy |

## 2.2 Remote Laboratories Directory Service

The aim the Remote laboratories directory service RLDS is to collect and cache information from RLs into a central database. RLDS can play an important role in addressing the issue of metadata discovery. Periodically, the EFHI API publishes data to the RLDS. The message contains attributes of the RL. The data stored in the RLDS will be consumed by the various applications, for example a web portal or a Moodle [8] Learning Tool Interoperability (LTI) plug-in.

A system administrator of the scheduler server can modify the resources referenced in the RLDS. However, to achieve more sustainability as mentioned by Salzmann and Gillet [9], the RLDS must be automatically updated from data provided by the RL with minimal human intervention. Furthermore, in order to cope with the dynamic nature of RLs, a scheduler must integrate state information over resources.

Figure 2 shows a simple JSON description of the RL inspired from Richter et al. [10]. The Rigs are classified in three main categories as follows:

1. General Attributes: unique identifier (_id), class, owner.
2. Scheduling Attributes: Boolean (isActive, status), lastAccess, duration in second.
3. Devices Attributes: URLs of different instruments and the switching matrix.

## 2.3 Client-Side Scheduler Service

Synchronization is a key concept for operating the three subsystems already mentioned. The HTML-interface of the Client-Side Scheduler is designed as a toolbox and integrates into the moodle application or a standalone application as a reusable component.

The client-side scheduler is a JavaScript function embedded in the client interface. The function is executed when the web page is first loaded and provides the user with the free RL data in a transparent manner.

```
{
        "_id":"13456789000098765",
        "index": 0,
        "class": "Analog practical work",
        "id": "101",
        "isActive": false,
        "lastAccess": tempsEnMs,
        "duration" : 30*10,
        "owner" : "idOwner",
        "Status": "online"
        "url":{
              "efhi":"http://192.168.10.10/v1",
              "dmm":"http://192.168.10.201",
              "dso": "http://192.168.10.200/rfp.html"
              }
}
```


**Fig. 2.** JSON description of the RL

The user gets a single token and register on the waiting list. It accesses an instance of the lab server, and then the client interface will create a WebSocket channel with the SS-Sc. A timer is used on the user side for synchronization with the scheduler. The WebSocket push method guarantees the synchronization. The lab server API checks the token and validates it with the SS-Sc.

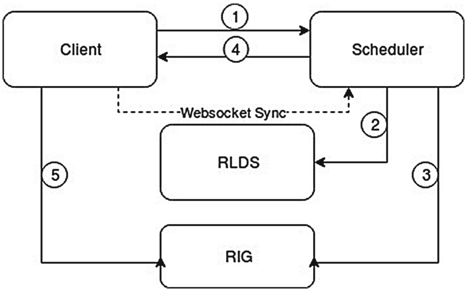


**Fig. 3.** Interaction steps of the scheduling service

The six steps of the interaction between the various components, as shown in Fig. 3, are explained below.

1. The student sends a request for the scheduler service; this request contains the identifier of the resource.
2. The scheduler service sends a request to the RLDS, which searches among all connected platforms and selects the available one. It returns a message to the scheduler containing the resource's UUID or an error.

3. The scheduler confirms the status of the rig by sending a confirmation message containing the user's token.
4. The scheduler sends in response to the client a message in JSON format containing the URLs of the various instruments connected to the switching matrix.
5. The client reloads the web page with the new settings and sets a timer in the interface.
6. A permanent channel is established with the scheduler. The API sync resource is used for this step.

The Fig. 4 shows the user interface of a measuring instrument and a timer. At the bottom of the page, browser debugging is enabled to view Ajax queries.

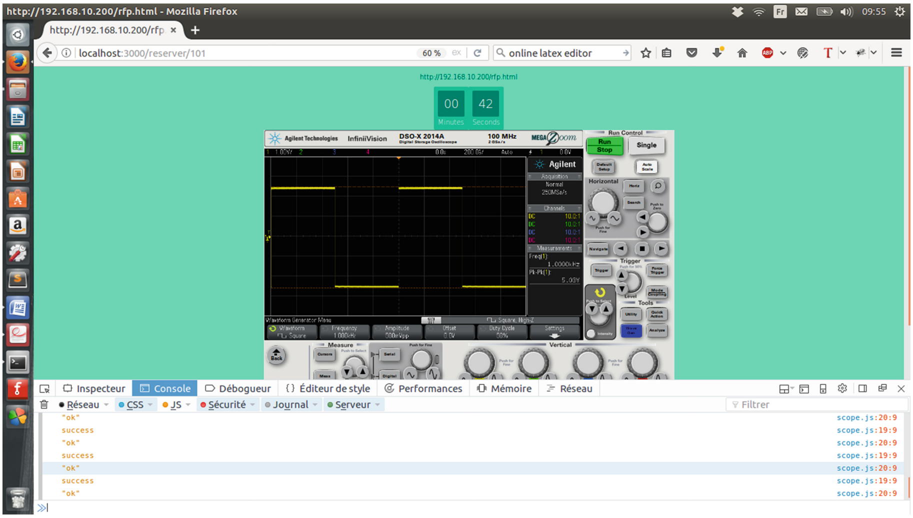


**Fig. 4.** User interface of the RL

## 3 Further Development

The product that is still in developmental state has been tested with four rigs. To move to the production stage a number of tasks must be carried out:

1. A full-scale test to verify the effectiveness of scheduler system.
2. A deployment will be implemented using multiple instances of RL partners.
3. A Management Service will be developed for monitoring the current status of the platform. It also allows managers to activate and deactivate RLs, and manage the sharing policy.
4. Other aspect of security will be studied and implemented.

## 4 Conclusion

This paper describes a scheduling management access to RLs. The proposed architecture has been successfully tested in the laboratory with four rigs. However, it must be validated in production with a larger scale platform assembly. Its effectiveness should be assessed.

## References


1. de Jong, T., Sotiriou, S., Gillet, D.: Innovations in STEM education: the Go-Lab federation of online labs. Smart Learn. Environ. **1**(1), 3 (2014)
2. Ferreira, J.M., Cardoso, A.M.: A Moodle extension to book online labs. In: Proceedings of the 2nd Remote Engineering and Virtual Instrumentation International Symposium (REV 2005) (2005)
3. Toderick, L., Mohammed, T., Tabrizi, M.H.: A reservation and equipment management system for secure hands-on remote labs for information technology students. In: 2005 Proceedings of 35th Annual Conference Frontiers in Education, FIE 2005, pp. S3F–S3F. IEEE, October 2005
4. Gallardo, A., Richter, T., Debicki, P., Bellido, L., Mateos, V., Villagrá, V.: A rig booking system for on-line laboratories. In: 2011 IEEE Global Engineering Education Conference (EDUCON), pp. 643–648. IEEE, April 2011
5. Vargas, H., Sánchez, J., Jara, C.A., Candelas, F.A., Torres, F., Dormido, S.: A network of automatic control web-based laboratories. IEEE Trans. Learn. Technol. **4**(3), 197–208 (2011)
6. Farah, S., Benachenhou, A., Neveux, G., Barataud, D.: Design of a flexible hardware interface for multiple remote electronic practical experiments of virtual laboratory. Int. J. Online Eng. **8**, 7–12 (2012)
7. Mini PC + Arduino (TM), pcDuino. http://www.pcduino.com
8. The Moodle course management system. http://moodle.org. Accessed July 2017
9. Salzmann, C., Gillet, D.: Challenges in remote laboratory sustainability. In: Proceedings of the ICEE 2007, (No. LA-CONF-2007-021) (2007)
10. Richter, T., Grube, P., Zutin, D.: A standardized metadata set for annotation of virtual and remote laboratories. In: 2012 IEEE International Symposium on Multimedia (ISM), pp. 451–456. IEEE, December 2012

# IoT Teaching with Pocket Labs

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**Abstract.** The IoT and Pocket Labs are popular buzzwords today with the IoT being much better known in wider circles, while the Pocket Labs is a relatively new concept offering new teaching opportunities which are to be further explored and analyzed. Although the IoT & Pocket Labs are not necessarily interconnected or mutually conditioned, this paper discusses such a real case of teaching practice, where the Pocket Labs are a natural solution for teaching of IoT. The paper deals with one semester teaching experience of IoT as a university course. Obtained results and experience may be quite general except for university students profile defined with their previous education and knowledge. Besides the main goal of the course which is an introduction to IoT, some other aims were exploring the social impact of IoT and emphasizing the importance of new original ideas and views being as important as mastering the IoT technologies.

**Keywords:** IoT · Pocket Labs · Teaching

## 1 Introduction

The IoT (Internet of Things) and Pocket Labs are popular buzzwords today with the IoT being much better known in wider circles, while the Pocket Labs are a relatively new concept offering new teaching opportunities which are to be further explored and analyzed. The IoT comprises many technologies working together to create a seamless link between real and virtual worlds that yields new qualities and benefits pervading our technical civilization. Some of the best-known technologies used by the IoT are RFID [1], WSAN (Wireless Sensors & Actuators Networks) [2], and Internet/web technologies integrating all aspects of the IoT [3]. Cloud computing has emerged as a virtual computing platform shifting the computing from traditional to SOC (Service Oriented Computing) based on SOA (Service Oriented Architecture) [4]. Due to the particular importance of the web, the Web of Things (WoT) is also considered [5], offering well-known web features for integration of remote devices and user interfaces. The rapid rise of interconnected devices equaling the number of people in 2011, along with growing expectation in the coming years, in both number and features [6] makes the ubicomp (ubiquitous computing) even more invisible and useful by seamlessly embedding devices working quietly and unnoticeably for our benefit [7, 8]. Such a situation naturally leads to increase of revenues and demand for educated professionals in the IoT technologies [9] and neighboring areas. Educational


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institutions, universities in the first place, should have a quick response for a demand of educated professionals of some new perspective educational profile. Furthermore, such a new demand should be foreseen thus resulting in a well-timed response. Adequate courses should be offered by competent faculties capable of providing required educational resources, the skilled staff and laboratory equipment. Staff should be competent with experience in a range of technologies important for the IoT. Besides the main educational focus, education of IoT professionals should provide certain broader knowledge and skills such as a social, thus having a "T" shaped educational profile [10]. The Pocket Labs (PLs) are a convenient educational concept based on small and cheap contemporary IT devices [11, 12] offering students to work on IoT projects while at lectures or when convenient at home. Although the IoT & PLs are not necessarily interconnected or mutually conditioned, this paper discusses such real teaching practice case where the use of PLs is considered as a natural solution for successful IoT teaching. The paper deals with one semester teaching experience of IoT university course held for the first time in the winter semester of 2016/17 academic school year. Obtained results and experience may be quite general except regarding the university students profile defined with their previous education and knowledge. The IoT course was prepared for the 4th year students of bachelor study program in general IT. Students had a good basic knowledge in various IT disciplines, but were lacking some preconditions such as previous knowledge in some engineering disciplines dealing with electronics, sensors, actuators, microcontrollers and similar. Besides the main goal of the course which is introduction to IoT, some other aims were exploring the social impact of IoT and emphasizing the importance of new original ideas and views which are as important as required good knowledge in technologies involved.

## 2 Motivation for Introduction of a New IoT Course

While considering the introduction of a new course dealing with the IoT for IT bachelor study program, one of the most important reasons was that the IoT was seen as an important emerging and fast developing ICT concept significantly influencing and changing many areas of human activity such as smart homes and cities, transport, trade, logistics, energy production, consumption and measurement, scientific research, health services, just to name a few. The future of IoT is viewed as a perspective with potential to bring significant improvements and benefits connecting real and virtual world of the Internet. At the same time, the current situation with existing IT study program was estimated as a mature and ready to support the teaching of IoT both with staff and new required equipment, for the new IoT lab. The introduction of the new IoT course was estimated to have multiple benefits for both students and the Institution. Students would obtain important contemporary foundation for IoT built upon the existing IT education, providing them with wider qualifications and increased competitiveness for the IT job market. Benefit for the Institution is increasing both the competence and competitiveness for the IT, so important for future development. A systematic study of the IoT also creates foundation and potential at the Institution for scientific research in the field. The IoT offers reliable and cheap hardware that can be used for a variety of students' practices in various study programs. It has already been used at the Institution as a basis for remote web experiments with real equipment and RFID attendance and access control of students and teaching staff.

## 3 Preparation and Planning

The new IoT course was offered for the first time as a course to be selected from the group of electives. The preparation of such a course was a challenge, as targeted students had almost no knowledge and experience with electronics and hardware, but had a solid knowledge and experience with programming of PC and similar platforms. As the sensors and various electronic components and devices are necessary hardware for interaction with the real world, laboratory exercises had to be planned and prepared as an adequate support and illustration for the theoretical part of the course. Such type of exercises is typical for study programs in sciences or engineering which have devoted laboratories that were planned and equipped well in advance. That has been the case with classical educational programs recognizable within longer time periods, but not with IT, and specially with some new fields of IT/ICT that can appear in a very short time period, become very important with quickly growing hardware and software support which cannot be ignored by the competent and competitive educational institutions, or otherwise they start to quickly lose competence and competitiveness with all logically deducible consequences. Therefore, the IT educational institutions need to be flexible with minimum inertia and to be able to offer state-of-the-art IT educational content. The IoT is an example of a new contemporary IT course that has requirements for specific equipment to be on disposal for students, or otherwise it cannot be adequately and effectively realized with all required educational qualities and goals. The experience with laboratory practice in existing courses from other study programs, like electronics and some other courses in physics, was transferred and used for planning the IoT lab within available time and physical resources. One more aspect of the IoT lab was regarded as very important, and that was the availability of the lab for each student to perform the required tasks individually and with minimum possible time limits. Such a requirement directly pointed to PLs [13, 14] and Flipped Lab [15, 16]. The PLs enable students to use educational equipment out of regular classes, at convenient place and time. The Flipped Lab (FL) concept as a special case of the Flipped Classroom (FC) being a wider notion, and in combination with the PLs put students in a position of being active and creative contributors of the educational process with choice of individual or collaborative work. The somewhat similar educational situation from the point of evaluation is with seminary work which also has to be explained and justified individually. The organization of a new modern IT course implies the competence of the teaching staff. Teaching competence is a complex notion that implies several important components. The first component above all is the adequate knowledge which must always exceed the course content. The second very important component is the experience and familiarity with the course content. Each member of the teaching staff should prove itself as authority for the subject during all phases of course teaching activities. A good teacher knows the background of the course, how things and concepts have evolved to become what they are today. Imaginative and innovative presenting of the course content should inspire students to start with their own unique original projects. Teaching staff should be active creators in the field of IoT to educate good developers. To be good in some area, it is not important to know everything, that is impossible, but to know the right things in the right amount. That is exactly the goal of teaching new technologies, to give the right knowledge in the right amount at right time and to give students creative tasks that will illustrate the power of IoT.

## 4 Content of the New IoT Course

New IoT course consists of theoretical lectures and laboratory practice with equipment supporting the IoT. Content of the IoT course was selected according to current knowledge and experience of teaching staff for IoT and some papers describing the IoT teaching at other institutions. As a result of literature review, it can be concluded that the IoT is present at educational institutions for two main reasons: (1) For purposes of studying the IoT as a course [9, 17–21], and/or (2) as an aid for teaching, with the IoT itself not being taught as a course [22–25]. The IoT as a general teaching aid dominates the presence of IoT in education comparing to IoT studying. That is similar to contemporary general IT being used as an important technology for education, and the IT studies in particular. The IoT becomes important for education as it already is for intelligent homes, cities, transport, and many other areas.

As already mentioned, the general IT students that attended the course were not familiar with some of the equipment required for the IoT. Special care was taken in order to cover such topics efficiently, giving necessary basics and leaving at the same time enough space for the most important IoT concepts that belong to IT which is students' primary competence. Competencies for the teaching staff both for the IoT theoretical lectures and practical laboratory exercises, include profound knowledge and working experience in many disciplines such as the general IT, microcontroller programming, electrical measurements and control, data acquisition, network programming, as the most important ones.

### 4.1 IoT Course Modules

The course content is modular with 6 modules selected to cover the most important aspects of the IoT.

The first module is introductory and devoted to "IoT How & Why", and practically unlimited perspectives based on innovative ideas & concepts and further science & technology advance. Students were encouraged to think freely and use imagination.

The second module "Signals & Measurements" covered the missing concepts related to basic electronic circuits, components, sensors, electrical measurements, actuators, control that IT students were not familiar with.

The third module covered the microcontrollers with emphasize on similarities & differences with microprocessors and when to use which. Third module was also a new one for students, but the main difference from the second module was that it was easier to base the new knowledge on previously existing IT knowledge and concepts, while for the new concepts in second module adequate base had also to be provided within the course.

The fourth module introduced the actual IoT devices which mainly consisted of various small microcontroller based boards and other electronic components which were used for the practical experimental work in this course.

The fifth module covered the IoT server programming or the “cloud” component of the IoT. Cloud support for the IoT is very important although less directly visible. That module was the easiest to build upon previous IT knowledge, as the students were already very well versed in network and web programming.

Finally, the sixth module introduced practical projects that integrated all previous modules.

Each of the modules also provided students with practical examples illustrating introduced concepts.

### 4.2 IoT Pocket Labs

The concept of the PLs ideally suited this IoT course. The course was supported by the host Institution and the Project (Acknowledgements), which provided each student during the course with required specific IoT equipment. Students used the IoT equipment during practical lessons, and were allowed to take the equipment for work at home or some other convenient place. In order to provide support for PLs and make it more effective, all teaching materials, examples, instructions and tasks were publicly available from the IoT course web page. The PLs helped students to compensate more easily for lessons they did not attend for various reasons. That gave students the opportunity not only to work through the course at their own pace, but also to try their own original solutions for tasks they were given. Starting with the tasks defined in detail, as the students advanced through the course, they were given tasks that were more loosely defined giving the opportunity for developing original concepts and solutions. Students presented their solutions and discussed differences and alternatives.

The PLs for the IoT course were based on the well-known Arduino family [26, 27] of boards and shields that proved to be adequate and reliable [28, 29]. Students used universal breadboards for creating electronic circuits with sensors and actuators. The PLs were combined with an excellent “Autodesk Circuits” [30] free on line simulator of electronic circuits which also included some of the Arduino boards. The online simulator further extended the PLs concept allowing students to try and experiment with many circuits and boards within the safe virtual environment. Projects created in simulator served as a documentation and prototypes for the real projects implemented with PLs. “Cloud” component of the IoT course was based on NodeJS [31] platform which made the choice of the “cloud” hardware platform irrelevant. NodeJS, a lightweight JavaScript runtime works well on any platform including SBC (Single Board Computers) for IoT. Students used the “Web Express” as a web server and additional modules like “serialport” for USB communication with Arduino boards and “socketsIO” for server initiated communication with clients when sending the IoT data. Such a concept allowed for use of existing regular PCs in computer classrooms for network connection with IoT devices. Some of the boards like ESP 8266 based, Arduino Ethernet and Yun which also has a lite Linux platform for NodeJS, were equipped with LAN interfaces. Students developed and tested network software for the IoT on PC platforms in NodeJS. In order to test it as the IoT, the Raspberry Pi SBC platform with Raspbian Linux was used, requiring minimal changes to NodeJS software developed for PC.

## 5 Experience with IoT Teaching

Although being an elective course among the alternative courses offered, the IoT course was selected by almost 100% of students. Some of the possible reasons for such an initial success were in the fact that the IoT was new, interesting, and attractive by itself. Students already had some notions and knowledge about the IoT. Some other possible reasons may be in the way it was promoted to students during presentation of electoral subjects, in order to give some basic information and help students to select one of the several subjects offered. Presentation for the IoT course included a demonstration of an interesting IoT WiFi device that was controlled with tablet. Students liked it very much, and showed immediate positive reaction. Presentations of other alternative courses offered, were not that attractive and effective. It seemed that students liked the IoT for what it can offer. Later during the IoT course, students showed interest and motivation, but not all of them. The two almost equal groups of students formed spontaneously, one consisting of students with regular attendance to lectures, and other where students did not attend IoT lessons regularly, with all consequences. But when it came to presentation of students’ projects, results of students that did not attend the IoT lessons regularly, were almost as good as results of students with regular attendance. Similar was during the final exam. Explanation for that could be in PLs that allowed students to study and work on their own. |The anticipated outcomes that were the motivation for creation and introduction of this new subject were fulfilled. The results achieved at the IoT exams were above the average. The students showed their motivation most when it came to design and implementation of their own IoT projects. Some projects were implemented using more advanced IT technology than that was presented on lectures. Students also demonstrated strong sense for the team work. As a rule of a thumb, students are attracted to courses where they can see the results of their work in the real world. The IoT enables them to create systems for control of real devices that interact with the physical world.

Besides covering and dealing with general IoT content, the IoT course can also be used as the basis for building the remote physics laboratories with web access for improvement of teaching physics. Some of the topics of seminary works for the IoT course can be defined by required physics experiments that will be prepared by physics department students in the role of the customer ordering the software with required characteristics.

While reconsidering the content of the IoT course after exams, an important topic was spotted as an appropriate to be added to the course in future, for a more general view of IoT. The new topic to be added is the IoT Architectural Reference Model (ARM), IoT-A [32] introducing the abstract IoT Reference Model and IoT Reference Architecture. A wide variety of IoT supported systems, IoT technologies and architectures require a unified approach to the development process for abstract modeling of a supported system and software architecture, with methodologies for creation of those abstract models, and for deriving specific system model and architecture for implementation. This is considered as important not only for the IoT design, but also as contributing to a wider picture of design in the IT, which is an important part of the IT education.

IT and IoT will certainly change in the future and become more advanced. One of the important indirect outcomes of this IoT course is to prepare and enable students to follow, learn and create the IoT technology of the future.

## 6 Students Projects

The group of 20 students selected the IoT course on the 4th year of general IT bachelor study group, which was almost a 100% of students on that study group, as only one student did not choose the IoT course. The evaluation consisted of usual 2 pre-exam tests, seminary work and a final exam, which was quite similar to evaluation of other subjects. Students were given a list of project titles to choose from, for their seminary work. Each topic for the seminary work was to be collaboratively done by the team of 4 students. Evaluation of the seminary work was on the individual basis. Each student had to describe his work and role on the project, and to answer very specific questions regarding project details and coding, as a proof and measure of his real engagement on the project. Each team passed through all the stages of the IoT development, consisting of electronics/sensors/actuators, microcontroller programing, web server and client programming. Web pages of two projects regarded as best, are shown in Fig. 1(a) and (b).

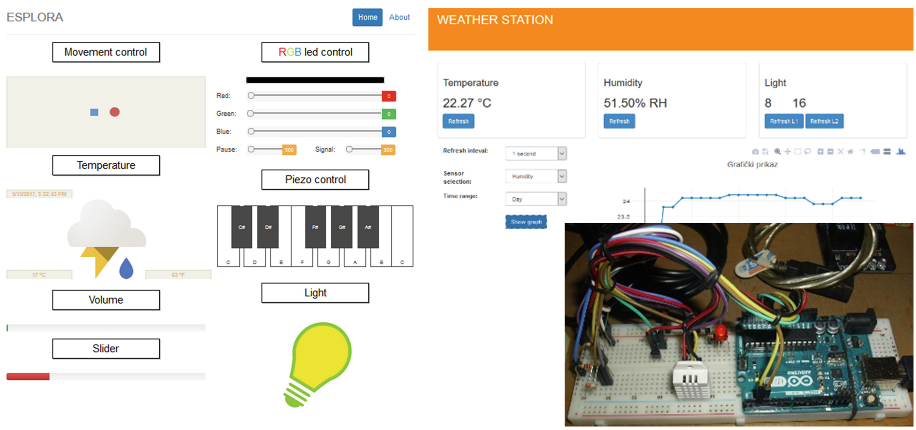


**Fig. 1.** Students' projects web pages: (a) left: Esplora control (b) right: weather station

Figure 1(a) shows the web page for remote control of the Esplora Arduino board [33] which is a small compact lab having various sensors and actuators. Implemented functionality is bidirectional allowing control of actuators on Esplora board from the web page and display of the sensors' values on the web page. Figure 1(b) shows the web page of weather station measuring and displaying air temperature, humidity, light intensities from two directions, numerically and graphically. On the lower right of Fig. 1(b) is a photo of a breadboard with meteorological sensors and electronics assembled by the students.

## 7 Conclusion

The IoT is an important contemporary concept for connecting of physical world with virtual world of digital technologies by means of sensors and actuators immersed in the physical world media of interest for monitoring and control. IoT combines various IT technologies for obtaining and collecting of physical data and control of actuators in various industries bringing new benefits and revenues. An adequate education of the IoT professionals is required for exploiting the IoT potentials and further development. University IT departments are privileged and expected to offer the contemporary cutting-edge IT education with IoT courses built upon IT foundation. As the IoT combines IT technologies with some engineering disciplines dealing with physical world interactions which are generally not part of the IT, the IoT courses require some support from engineering, as the IoT courses for engineering students would require some support from the IT. The IoT only explicitly requires what is implicit for the IT, that development of the IT support for some real-world system always requires some knowledge of the system expressed in the system model. That implies the "T" shaped educational profile with solid basis of the main studies extended towards some more peripheral content estimated as important. Besides the necessary IT and engineering content of the IoT course, some wider view of the IoT should be provided due to the diversity of supported systems and IoT technologies in the form of the IoT ARM (IoT-A) which introduces the abstract reference model and reference architecture as common for any IoT project. The IoT-A also specifies methodologies for creation of abstract models and obtaining required specific model and architecture for implementation.

Staff competencies for the IoT teaching are seen as comprising not only the knowledge which must exceed the course content, but also the operational experience and ability to motivate students for non-constrained thinking and original solutions.

One of the goals of the IoT course should be the "education for future", enabling students to learn, use and create the IoT of tomorrow.

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Devoted to my dear IT bachelor students of the 4th year during 2016/2017 IoT course.

## References


1. Jia, X., Feng, Q., Fan, T., Lei, Q.: RFID technology and its applications in Internet of Things (IoT). In: 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet), Yichang, China, 21–23 April 2012 (2012)
2. Zhu, Q., Wang, R., Chen, Q., Liu, Y., Qin, W.: IOT Gateway: bridging wireless sensor networks into internet of things. In: IEEE/IFIP International Conference on Embedded and Ubiquitous Computing, Hong Kong, China, 11–13 December 2010 (2010)
3. Atzori, L., Iera, A., Morabito, G.: The internet of things a survey. Comput. Netw. **54**, 2787–2805 (2010)
4. Miorandi, D., Sicari, S., Pellegrini, F., Chlamtac, I.: Internet of things: vision, applications and research challenges. Ad Hoc Netw. **10**, 1497–1516 (2012)
5. Guinard, D., Trifa, V., Wilde, E.: Architecting a mashable open World Wide Web of things. Technical report 663, Institute for Pervasive Computing, ETH Zürich (2010). https://dret.net/biblio/reference/gui10a, http://e-collection.library.ethz.ch/eserv/eth:5072/eth-5072-01.pdf
6. Internet of Things in 2020 a roadmap for the future INFSO D.4 networked enterprise & RFID INFSO G.2 micro & nanosystems in co-operation with the RFID working group of the european technology platform on smart systems integration (EPoSS) (2008). http://www.smart-systems-integration.org/public/documents/publications/Internet-of-Things_in_2020_EC-EPoSS_Workshop_Report_2008_v3.pdf
7. Weiser, M., Gold, R., Brown, J.: The origins of ubiquitous computing research at PARC in the late 1980s. IBM Syst. J. **38**(4), 693–696 (1999)
8. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of Things (IoT): a vision, architectural elements, and future directions. Future Gener. Comput. Syst. **29**, 1645–1660 (2013)
9. Ali, F.: Teaching the internet of things concepts. In: Workshop on Embedded and Cyber-Physical Systems Education, Amsterdam, Netherlands, 4–9 October 2015, no. 10, pp. 10:1–10:6 (2016)
10. H2020 Work Programme 2014–2015, ICT-30-2015: Internet of Things and Platforms for Connected Smart Objects Supporting Internet of Things, Activities on Innovation Ecosystems, Report on the factors of user's acceptance framework and societal and education stakeholders. http://www.internet-of-things-research.eu/pdf/D04_01_WP04_H2020_UNIFY-IoT_Final.pdf
11. Klinger, T., Madritsch, C.: Use of virtual and pocket labs in education (Demo). In: 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), 24–26 February 2016, pp. 261–262. UNED, Madrid (2016)
12. Madritsch, C., Klinger, T., Pester, A., Schwab, W.: Work in progress: using pocket labs in master degree programs. In: Auer, M., Guralnick, D., Uhomoibhi, J. (eds.) Interactive Collaborative Learning. ICL 2016. Advances in Intelligent Systems and Computing, vol. 545. Springer, Cham (2017)
13. Klinger, T., Madritsch, C.: Collaborative learning using pocket labs. In: 9th International Conference on Interactive Mobile Communication Technologies and Learning, IMCL2015, Thessaloniki, Greece, 19–20 November 2015, pp. 185–189 (2015)
14. Paulson, M.: Experimental Learning in Mechatronics: The Lab in your pocket. Report, Göteborgs universitet (2011). https://gupea.ub.gu.se/handle/2077/18128
15. Raman, R.: Flipped labs as a smart ICT innovation: modeling its diffusion among interinfluencing potential adopters. In: El-Alfy, E.S., Thampi, S., Takagi, H., Piramuthu, S., Hanne, T. (eds.) Advances in Intelligent Informatics. Advances in Intelligent Systems and Computing, vol. 320. Springer, Cham (2015)

16. Meier, R.: Keynote at: 13th International Conference on Remote Engineering and Virtual Instrumentation REV2016, UNED, Madrid, Spain, 24–26 February 2016 (2016). http://rev-conference.org/REV2016/documents/keynote_Meier.pdf
17. Kortuem, G., Bandara, A., Smith, N., Richards, M., Petre, M.: Educating the internet-of-things generation. Computer **46**(2), 53–61 (2013)
18. He, J., Lo, D., Xie, Y., Lartigue, J.: Integrating Internet of Things (IoT) into STEM undergraduate education: case study of a modern technology infused courseware for embedded system course. In: IEEE Frontiers in Education Conference, Erie, PA, USA, 12–15 October 2016, pp. 1–9 (2016)
19. Dobrilovic, D., Covic, Z., Stojanov, Z., Brtka, V.: Approach in teaching wireless sensor networks and IoT enabling technologies in undergraduate University courses. In: 2nd Regional Conference Mechatronics in Practice and Education – MECHEDU 2013, Subotica, Serbia, 5–6 December 2013, pp. 18–22 (2013)
20. Bogdanovic, Z., Simic, K., Milutinovic, M., Radenkovic, B., Despotovic-Zrakic, M.: A platform for learning internet of things. In: 8th International Conference on e-Learning, Lisbon, Portugal, 15–18 July 2014, pp. 259–266 (2014)
21. Simic, K., Vujin, V., Labus, A., Stepanic, Đ., Stevanović, M.: Designing environment for teaching internet of things. In: 8th International Conference on e-Learning, Lisbon, Portugal, 15–18 July 2014, pp. 415–417 (2014)
22. Cheng, H., Liao, W.: Establishing an lifelong learning environment using IOT and learning analytics. In: 14th International Conference on Advanced Communication Technology (ICACT), Pyeongchang, South Korea, 19–22 February 2012, pp. 1178–1183 (2012)
23. Chin, C., Callaghan, V.: Educational living labs: a novel internet-of-things based approach to teaching and research. In: 9th International Conference on Intelligent Environments, Athens, Greece, 16–17 July 2013, pp. 92–99 (2013)
24. Lamri, M., Akrouf, S., Boubetra, A., Merabet, A., Selmani, L., Boubetra, D.: From local teaching to distant teaching through IoT interoperability. In: International Conference on Interactive Mobile Communication Technologies and Learning (IMCL2014), Thessaloniki, Greece, 13–14 November 2014, pp. 107–110 (2014)
25. Gomez, J., Huete, J.F., Hoyos, O., Perez, L., Grigori, D.: Interaction system based on internet of things as support for education. In: The 4th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2013), Niagara Falls, Ontario, Canada, 21–24 October 2013, pp. 132–139 (2013)
26. Arduino family of boards. http://arduino.org
27. Arduino family of boards. http://arduino.cc
28. Cvjetkovic, V., Matijević, M.: Overview of architectures with Arduino boards as building blocks for data acquisition and control systems. In: 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), UNED, Madrid, Spain, 24–26 February 2016 (2016)
29. Cvjetkovic, V., Stankovic, U.: Arduino based physics and engineering remote laboratory. In: 19th International Conference on Interactive Collaborative Learning ICL2016, Clayton Hotel, Belfast, UK, 21–23 September 2016 (2016)
30. Autodesk Circuits. https://circuits.io/
31. NodeJS platform. http://nodejs.org
32. Bassi, A., Bauer, M., Fiedler, M., Kramp, T., van Kranenburg, R., Lange, S., Meissner, S. (eds.): Enabling Things to Talk - Designing IoT solutions with the IoT Architectural Reference Model. Springer Open (2013). http://www.springer.com/us/book/9783642404023
33. Esplora Arduino board. http://www.arduino.org/products/boards/arduino-esplora

# An Activity Tracking Infrastructure for Embedded Open Educational Labs Supporting the Needs of Lab Owners and Students

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**Abstract.** Remote labs are interactive Open Educational Resources, where user's action generates a wealth of data belonging to two categories: interaction data resulting from the use of the client web app, and experimental data resulting from performing the experiment. Many entities are interested in deriving insights from the user's generated data: students, teachers, institutions, and lab providers. In this work we consider to needs of students and lab owners as stakeholders. Through questionnaires we find out that students want to save and retrieve their experimental results and have awareness about their progress relative to others, while lab owners want to understand how their labs are used in order to provide better services and advertise their labs. Given that students and lab owners have different interests in the data, we address their differing needs by proposing an architecture for an activity tracking infrastructure, an accompanying vocabulary to formalize the tracks, and present a use case.

**Keywords:** Remote laboratories · Open educational labs
Activity tracking · xAPI

## 1 Introduction

Online lessons for STEM education are composed of a collection of Open Educational Resources (OER) such as slides, videos, interactive content such as remote laboratories (RL). Often RLs are integrated in online platforms within a lesson as Open Educational Labs (OEL, presented in Sect. 2.1). The affordance of digital tracking technologies provides a valuable source of information: learning behaviors, user interaction, and equipment use can be quantified, analyzed, and understood. Through questionnaires sent to students and lab owners, we find out that visualizations showing the status of participants in a same class help


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students in observing, reflecting upon their personal progress, and taking steps to adjust their procedures to attain their goal. A notion often referred to as *awareness and reflection to self-regulate* [1]. Lab owners as service providers are interested in understanding how their labs are used, in order to provide better services and advertise for their labs in repositories, which are the equivalent of electronic catalogues. As the use of remote labs is often hindered by the unawareness of its availability, lab owners are interested in sharing their usage statistics to advertise for their remote labs on these repositories.

Presenting the data to the learners in a meaningful and relevant fashion depends not only on the visualization technologies, but also on the underlying infrastructure which collects and stores activity traces. Most existing solutions for activity tracking in educational settings capture the interaction of the user with the platform rather than with the embedded resources [9]. To the extent of our knowledge, there are no existing frameworks for tracking activities in remote lab applications taking into consideration the differing needs of students and lab owners. In this work, we aim to answer the following research questions: what are relevant traces for students and lab owners, and what data is needed to answer questions posed by learning analytics? Do we need separate repositories for the data of the students and the lab owners? How do we describe these traces? Are existing formalized vocabularies enough for capturing the experiences in remote labs?

This paper is structured as follows: first we start by providing the context of this paper and related works, then we present our proposed activity tracking infrastructure. In a following section we provide an implementation example with an extended xAPI vocabulary, and last we conclude.

## 2 Related Works

### 2.1 Open Educational Labs

Remote labs (RL) are real physical labs which can be controlled and monitored at distance using web applications. Open Educational Labs (OEL) are a reference and an extension of the Open Educational Resources, OEL is based on the importance of using well-integrated remote labs in the hosting educational platforms. In [6] we define integration layers which communicate through defined interfaces. The first layer includes the physical equipment of a remote lab and is abstracted as a set of software services based on the Smart Device paradigm. Accordingly an RL is represented as a set of services exposed through a well-defined API [11]. The API provides endpoints to accept requests for: data retrieval from the sensors which convey the state of the lab, configuration data which puts the lab in a certain operational mode if supported, and pushing commands to actuators for controlling the lab. This layer is accessible to any application trying to interact with the lab. Next, the remote lab can be personalized as an Open Educational Lab (OEL) by the development of a user application integrating the pedagogical elements required by the learning context, and which is augmented with the necessary functionalities to insure proper communication with the hosting platform and the interfacing with the lab. Last in Layer 3, the OEL is integrated in a hosting platform while insuring the propagation of contextual information, user activity traces, as well as data related to the experimentation itself.

In this paper, we propose an architecture for supporting the collection and propagation of student and lab owner related data, which will be respectively used in learning platforms and lab repositories.

### 2.2 Existing Activity Tracking Infrastructures

A number of activity tracking frameworks which can be utilized for educational settings exist. For example, there are the "all-purpose" solutions such as Google Analytics[1] (GA). GA provides rich APIs to save the traces to Goolgle's servers, which can be then visualized on the Google Analytics platform, the data can then be manually exported into various useful formats, or programmatically through the Analytics Reporting API.[2] GA represents two limitations for our purposes: first although the APIs are flexible, they limit the use of fields for saving the tracks which could lead to losing granularity in actions description, leading to limitations in studying the data. Second, since the data are saved on the Google servers, which causes many privacy problems related to governmental and institutional guidelines.

In [8], the authors propose a "flexible" and "extendable" learning analytics infrastructure. Their design is based on 3 requirements: action logging, user feedback, and ex-post analysis. This respectively means that a user can save and retrieve data related to their activity on a web-based learning platform, can receive feedback from the infrastructure for guidance, and teachers can utilize the collected data over time to study learning traces at scale. While their approach supports three important services of a leaning analytics infrastructure, the collected data can only be used in proprietary analysis tools.

In [14,15], the authors present a contextual solution to save students tracks. The architecture enables teachers to chose whether they want to track students online or not, and accordingly can then use awareness and reflection tools to pull user data in a specific context (online lesson), and vizualise them in dashboards. While this solution contextualizes learning analytics, it doesn't enable students to get their data unless the teacher chooses to. This solution is designed to mainly support teachers in understanding the dynamics of an online class. With this solution, the learning traces are saved in the embedding platform, and only accessible through it to enforce privacy.

## 3 Eliciting the Needs of Lab Owners and Students

### 3.1 Students Needs

We send out another questionnaire[3] to students of the Control Systems course at EPFL. The students have ex-cathedra lectures and do the lab exercises through a

[1] https://developers.google.com/analytics/.
[2] https://developers.google.com/analytics/devguides/reporting/core/v4/.
[3] https://goo.gl/WhghKG.

MOOC on a local instance of edX. The aim of the questionnaire is to understand what interests students in the dynamics of a lab session: progress of classmates, how they know if they are on the right track, what kind of problems they face, how they solve them, and how they expect to solve them when away from the physical lab. 62.5% of the 24 responders say that they are interested in knowing the progress of the rest of the class. The most encountered problem is getting wrong values (70.8%), and for that 83.3% of the responders check with other classmates what could have gone wrong. While students don't check the steps taken so far if they are not stuck (16.7%), 50% often check the experimental values with others regardless. 62.5% of the responders found activity dashboards very useful. 79.2% of the students said they would use the dashboards to check the correctness of their steps in experimentation, 75% think they provide a platform to reflect upon their progress. Students are mostly interested in knowing the experimental results of others (83.33%) and their steps (66.7%). 70.9% think it is important to have the experimental data linked to their actions. 79.2% of the responders found it useful to be able to save and retrieve data on the platform, and want to be able to save their experimental data for their own records. 79.2% of the responders are willing to share their data if asked to.

### 3.2 Lab Owner Needs

We design a questionnaire[4] to understand the monitoring needs of remote lab owners. The questionnaire was sent to 80 lab owners. Only one of the 18 responders didn't set up monitoring for their labs. 73.3% of responders monitored the *duration of connection* of users, 66.7% tracked the *measurements*, 80% kept record of the *connected users*. Other monitored indicators include where the lab was accessed from (LMS, direct access, or other), web browser used, IP address, geolocation, queuing duration, language used, internal events such as hardware interlocks, alarms, and others. In order of ranking, lab owners monitored for *statistics of lab usage* (86.67%), *failure/security auditing* (86.67%), *load balancing* (60%), and *system modeling* (42.22%). 14 responders found monitoring their labs useful, while only 2 found it to be not very useful. 3 did not share their monitoring data, while others published them to a variety of channels: lab repositories, hosting RLMS (Remote Lab Management System), Slack channels, or standalone lab page. The lab owners who didn't publish their monitoring data said that they are not interested in sharing their data publicly, that they used them for their own internal reporting, or only published them in scientific papers.

## 4 Activity Tracking Infrastructure for Embedded OEL

Following the elicitation of needs for lab owners and students, we see that the two stakeholders have different needs. Students need to be supported in awareness

[4] https://goo.gl/fLWUlU.

and reflection, and they should be able to save and retrieve their experimental data. Lab owners want to understand how their labs are used and make available their monitoring data to lab repositories. Hereafter we detail our proposed architecture for saving activity traces for remote labs.

### 4.1 Designing for Students

As elicited in Sect. 3.1, students need three things: have enough information to be able to self-regulate, save and retrieve experimental data, and to export their activity traces and experimental results. We outline the following considerations for the architecture supporting students:

– Tracking how students use the OEL is enough for the purposes and needs of students. For example, if a user controls an actuator, this will be through an event on the web interface of the OEL which can be captured, and activity traces can be built on that.
– The storage system keeping the students' activity traces and their experimental results is different than the one used by the lab owner as it will be discussed in Sect. 4.2.
– The storage system should have both the activity traces and experimental results of students. This is because saving and retrieving data are associated with user's activity having certain connotations: for example *saving* the results because an experiment is *finished*. Or *retrieving* them to *analyse* them.

### 4.2 Designing for Lab Owners

Referring to the questionnaire discussed in Sect. 3.2, we conclude that the majority of lab owners are interested in keeping records of the usage of their labs, value the importance of the insights they can derive from them, and some of them already publish these data to inform about the status of their labs. Additionally, from a lab owner's perspective, a remote laboratory implemented as an OEL could be used in different platforms. Hence, having a solution which makes it possible to aggregate all the traces for a given lab with minimal effort is important. From this we can draw the following design considerations:

– Each remote lab should have its own activity tracking storage system.
– Due to governmental and institutional regulations, sharing the real identity of users can pose major privacy issues, which would hinder the ability of lab owners to monitor their labs. Hence, lab owners can resort to tracking without knowledge of the identity of the users, and so monitoring can happen independently from hosting platforms.
– Lab owners should have a solution which makes it possible to easily push their data to lab repositories.

Combining the design requirements for both students and lab owners, Fig. 1 depicts our complete proposal for an activity tracking infrastructure independent from the embedding platform.

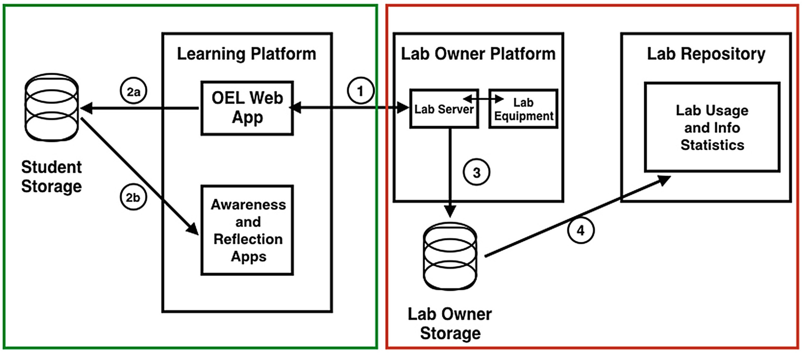


**Fig. 1.** Activity tracking architecture for remote labs

The green box in Fig. 1 comprises the elements needed for the students design. The **OEL Web App** embedded in a **Learning Platform** such as edX or Moodle, connects to the **Lab Owner Platform** to provide access to the remote lab in ①. The **OEL Web App** authenticates and connects to a storage system dedicated for the students activity traces and associated experimental data. This is shown with the arrow (2a). As mentioned in earlier sections, students are interested in the insights these data can bring for *awareness and reflection*. Tools dedicated for to students and embedded in the learning platform consume these data by first authenticating before retrieving and consuming the data in (2b). Students should also be able retrieve their experimental data from the storage and use them in tools available on the platform to study the data, such as graphing tools.

The red box is dedicated to the lab owner in the infrastructure. The **Lab Owner Platform** is composed of the **Lab Server** and the **Lab Equipment**. The **Lab Server** provides public APIs for the **OEL Web App** embedded in a **Learning Platform** to connect and use the **Lab Equipment**. Once a student connects to the **Learning Platform**, and the **OEL Web App** connects to the **Lab Server** as shown with arrow ①, the lab owner detects the event and starts pushing the activity traces s/he wants to save, to a storage system dedicated for the remote lab in question in ② after authentication. As per the availability of data, the lab owner pushes it to lab repositories to display various indicators of the lab availability and usage (for .e.g. number of users over time and availability of the lab) in ④.

It is worth mentioning that in this work we don't address authentication and privacy issues which are an integral part of this infrastructure. In [5], we address privacy of students by proposing an agent based privacy management system, where students can control data access of the infrastructure.

## 5 Implementation Example

The Mach-Zehnder interferometer example[5] considered in this work is configured to study light interference [4,7]. Teachers can find the lab on an online lab repository: Golabz[6] and integrate it in *graasp* as an OEL (as described in Sect. 2.1). Graasp[7] is an educational social media platform, which allows teachers to author a learning activity called the Inquiry Learning Space (ILS). ILS implements a structured learning model where students proceed through pre-set educational phases. They are first oriented about a subject, then they are asked to conceptualize or hypothesis about it, next they experiment to prove or refute their hypothesis, and last they conclude [3]. Each phase of the ILS has teacher-curated OERs and OELs which make the ILS a rich OER [10]. In our example, the remote lab will be embedded in an ILS, at the stage where students are experimenting: the Investigation phase. We show how the proposed activity tracking infrastructure is utilized by lab owners through exporting the data to Golabz, and by students through an awareness app which shows the number of actions done by the student in the lab.

In this implementation example we adopt the xAPI[8] specification for saving activity traces and related artifacts (the experimental data). xAPI provides guidelines on how to capture user interaction with an online environment, and formalizes the formats of those traces. An xAPI compatible storage system is called a Learning Record Score (LRS), which verifies the format of statements before allowing them to be saved. An xAPI statement is made of two components: the format, in its most basic form *actor-verb-object*, and the vocabulary which is used to write the statements describing each component. xAPI also provides guidelines on statement design [13], and ready to use recipes [12]. A recipe is a standard vocabulary to be used to describe an experience, to avoid the use of different vocabularies for the same kind of experiences. To the extent of our knowledge, there isn't any recipe for Remote Experimentation, and hence we define two: one for lab owners, and the other for students. Due space constraints, below we provide a high-level description of both recipes.

**xAPI Recipe for Students.** This recipe defines the structure and terms used in xAPI statements to record an online experimentation activity as seen by a student. Hereafter we follow an xAPI structure of defining a recipe:

**Basics.** All statements include the recipe ID, the *actor* as the person being observed, the *object* as the OEL element the user is interacting with (e.g. slider), and all statements are timestamped.

**Activities.** We define two types of activities: *root* and *item* activities. The *root* activity identifies the OEL as a whole. These activities relate to an

[5] https://goo.gl/NtDd45.
[6] http://golabz.eu.
[7] http://graasp.eu.
[8] http://experienceapi.com/.

activity happening on the high level of the OEL such as the student *opens* and *closes* it. The *item* activity related to action on one element of the OEL, such as moving a slider.

**Statements.** The following statements are considered as the most basic to capture student experience: *opened* or *closed* the OEL, *read* from a sensor, *wrote* to an actuator, *saved* the experimental data, *retrieved* the experimental data.

**xAPI Recipe for Lab Owners.** This recipe defines the structure and terms used in xAPI statements to record an online experimentation activity, when the lab owner is the observer:

**Basics.** All statements include the recipe ID, the *actor* as the person being observed, the *object* as a sensor or actuator, and all statements are timestamped.

**Activities.** We define two types of activities: *root* and *item* activities. The *root* activity identifies the remote lab equipment as a whole. These activities affect the whole remote lab setup, such as a user is *connects* and *disconnects*. The *item* activity is exerted on one component of the lab setup, such as a sensor or an actuator.

**Statements.** For a lab owner to capture relevant traces, the following statements are considered mandatory: *connected* or *disconnected* from the lab, *read* sensor value, or *wrote* value to an actuator.

In Fig. 2 we show how the complete infrastructure works in our example. On the right side of the figure, first the **OEL Web App** connects to the **Lab Server** which starts pushing activity traces to the lab owner's specified LRS. This **Lab Server** uses the TinCanJs[9] library to connect, authenticate, and push xAPI validated statements to the LRS. The lab owner should have knowledge of the endpoints of the LRS and have credentials. To export the collected data to visualizations on Golabz, an embedded widget connects to the LRS of the lab owner with the same credentials, retrieves and graphs reports. As we use the LearningLocker in this example, the lab owner should first create a 'Report' with his/her account, and provide the graphing widget with the report id. A report in the LearningLocker is structured data which can be exported in various formats, in our case we choose the JSON[10] format. In this example, the lab owner chooses to show the number of actions done on the lab equipment during the month of July 2017.

In step 4 the **OEL Web App** connects to the students LRS and pushes interaction data and experimental results. The student provides the **OEL Web App** with credentials to connect to their specified LRS, and the same library and authentication mechanism is used in this case as in the lab server. Last in step 5, we see an app embedded in the ILS which retrieves and graphs data from the student LRS. We use the TinCanJs library to query the LRS using the

[9] http://rusticisoftware.github.io/TinCanJS/.

[10] http://www.json.org/.

user identification and LRS authentication credentials known to the **OEL Web App**. In Fig. 2, the app shows the user how many actions s/he did using the lab on the 2 days s/he connected to it. For the graphs of both the lab owners and students we use the Highcharts[11] graphing library.

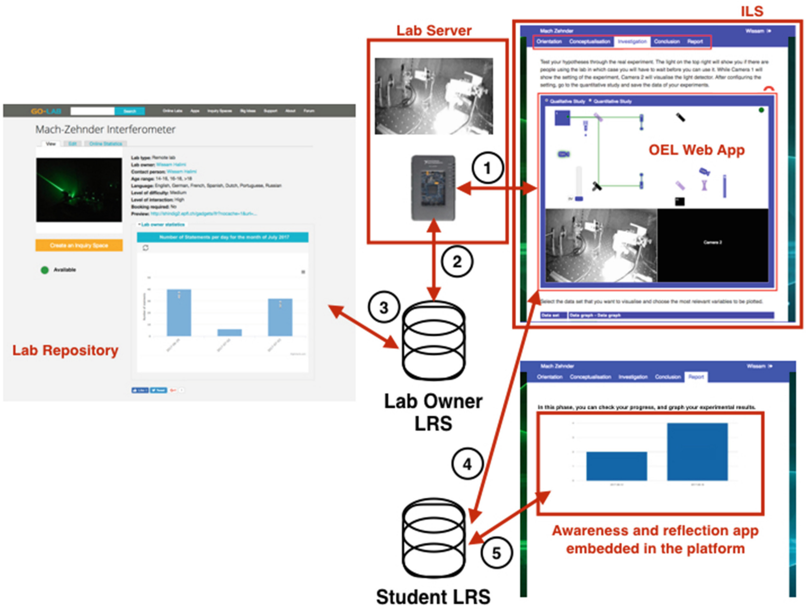


**Fig. 2.** The complete implementation example following our proposed architecture for lab owners and students

## 6 Discussion

The presented work frees the data collected for lab owners and students from proprietary formatting and use by the hosting platforms. With such an open design, many authentication and privacy issues can be encountered. As mentioned earlier in Sect. 4, in [5] we handle the privacy of students. We wanted to provide students with a solution which makes it possible for them to choose where to save their experimental activity. One of the main enabling factors of such an infrastructure is the interoperability of students' generated data once formatted in an xAPI format. In [2], the authors detail compatibility tests run on three major LRS providers: Learning Locker, Watershed LRS,[12] and WaxLRS.[13]

[11] https://www.highcharts.com/.
[12] https://www.watershedlrs.com/.
[13] http://www.saltbox.com/.

They show in this work how many modalities can be implemented to migrate the data to and from the different LRSes. This proves that if students choose LRSes from different providers, this will not hinder the operation of all the awareness and reflection applications which consume the data of all the students in an online course. And given that these LRS solutions are required to implement the xAPI specification, the TinCanJs library used in the implementation example in Sect. 5 should be able to handle the authentication and interfacing with these different LRS solutions with minimal or no effort.

## 7 Conclusion and Future Work

In this work we proposed an activity tracking infrastructure for OELs independently of embedding platforms, while taking into consideration the differing needs of students and lab owners. The proposed architecture is accompanied by an extended xAPI vocabulary for activity traces, formalizing xAPI statements for remote labs. With this infrastructure, the collected data is freed from proprietary formatting and use of the embedding platforms. This work also covers the cases where the embedding platforms do not provide mechanisms for storage, and prevents putting in place an ad-hoc solution. Students can export the data to be saved for their own archiving purposes, and benefit from different awareness and reflection apps. Lab owners can collect in one place as much data as possible about how a given lab is used, providing them with substantive data to be analysed for better maintaining their labs, and to be sent to lab repositories for better advertisement. We also presented an implementation example, showing how the OEL concept is more complete with the proposed activity tracking infrastructure for remote labs, and how the continuity of the learning activity is supported for students, when they are able to save retrived their data in the same context. As mentioned in Sect. 4.1, there are privacy concerns when the architecture is open and data can be shared, a matter which we address in [5].

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## References


1. Dillenbourg, P., Zufferey, G., Alavi, H., Jermann, P., Do-Lenh, S., Bonnard, Q., Cuendet, S., Kaplan, F.: Classroom orchestration: the third circle of usability. In: CSCL2011 Proceedings, vol. 1, pp. 510–517 (2011)
2. Downes, A., Shahrazad, A., Smith, R.: Sharing between LRSs: a collaborative experiment in practical interoperability (2015)
3. Gillet, D., De Jong, T., Sotirou, S., Salzmann, C.: Personalised learning spaces and federated online labs for stem education at school. In: 2013 IEEE Global Engineering Education Conference (EDUCON), pp. 769–773. IEEE (2013)
4. Halimi, W., Salzmann, C., Gillet, D.: The Mach-Zehnder interferometer: a smart remote experiment based on a software template. In: 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 287–292. IEEE (2016)
5. Halimi, W., Salzmann, C., Gillet, D.: Managing privacy in activity tracking for remote labs. In: 7th Work Engineering Education Forum (WEEF). Under review (2017)
6. Halimi, W., Salzmann, C., Gillet, D., Saliah-Hassane, H.: Standardization layers for remote laboratories as services and open educational resources. In: International Conference on Remote Engineering and Virtual Instrumentation (REV). Springer (2017, in press)
7. Halimi, W., Salzmann, C., Jamkojian, H., Gillet, D.: Enabling the automatic generation of user interfaces for remote laboratories. In: International Conference on Remote Engineering and Virtual Instrumentation (REV). Springer (2017, in press)
8. Hecking, T., Manske, S., Bollen, L., Govaerts, S., Vozniuk, A., Hoppe, H.U.: A flexible and extendable learning analytics infrastructure. In: International Conference on Web-Based Learning, pp. 123–132. Springer (2014)
9. Orduna, P., Almeida, A., López-de Ipina, D., Garcia-Zubia, J.: Learning analytics on federated remote laboratories: tips and techniques. In: 2014 IEEE Global Engineering Education Conference (EDUCON), pp. 299–305. IEEE (2014)
10. Rodríguez-Triana, M.J., Govaerts, S., Halimi, W., Holzer, A., Salzmann, C., Vozniuk, A., de Jong, T., Sotirou, S., Gillet, D.: Rich open educational resources for personal and inquiry learning: agile creation, sharing and reuse in educational social media platforms. In: 2014 International Conference on Web and Open Access to Learning (ICWOAL), pp. 1–6. IEEE (2014)
11. Salzmann, C., Govaerts, S., Halimi, W., Gillet, D.: The smart device specification for remote labs. In: 2015 12th international conference on Remote Engineering and Virtual Instrumentation, pp. 199–208. IEEE (2015)
12. TinCan/xAPI: Recipes: How it works. http://tincanapi.com/recipeshow-it-works/
13. TinCan/xAPI: Statement design. http://experienceapi.com/statement-design/
14. Vozniuk, A.: Enhancing Social Media Platforms for Educational and Humanitarian Knowledge Sharing: Analytics, Privacy, Discovery, and Delivery Aspects. Ph.D. thesis, École Polytechnique Fédérale de Lausanne (2017)
15. Vozniuk, A., Govaerts, S., Bollen, L., Manske, S., Hecking, T., Gillet, D.: AngeLA: putting the teacher in control of student privacy in the online classroom. In: 2014 Proceedings of Information Technology Based Higher Education and Training (ITHET), pp. 1–4. IEEE (2014)

# Development and Use of a Virtual Laboratory of Measuring Devices

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**Abstract.** Development and extensive use of virtual laboratories (VLs) in various subject domains is a really actual practical task of our time. Universal platforms such as Unity, OpenSim as well as object-oriented and web-oriented high-level languages (C, Java, PHP) are used for VLs implementation. A significant progress has already been achieved in simulation (modeling) of real-world objects and systems, in providing a trainee's interface, as well as in forming a bank of exercises and tasks. But the task of trainees' actions assessment in VLs has not yet been solved in its full completeness. The goals of this research work are: to develop a mathematical model of a virtual laboratory, which includes a complex of computer-based simulation systems of measuring devices; to develop a method of trainee's actions assessment in a virtual laboratory; to realize and integrate a virtual laboratory into the learning process.

**Keywords:** Virtual laboratory · Simulation system · Training process

## 1 Introduction

Development and extensive use of virtual laboratories (VLs) in various subject domains is a really actual practical task of our time. Universal platforms such as Unity, OpenSim as well as object-oriented and web-oriented high-level languages (C, Java, PHP) are used for VLs implementation. A significant progress has already been achieved in simulation (modeling) of real-world objects and systems, in providing a trainee's interface, as well as in forming a bank of exercises and tasks. But the task of trainees' actions assessment in VLs has not yet been solved in its full completeness.

## 2 The Problem

There are a number of simulators [1, 2] and virtual work environments for students and employees training [3, 4]. Trainees often have errors, difficulties in performing exercises and achieving certain goals in virtual workplace training. Expert assessment is the most effective approach to trainee's errors diagnosis when he/she is working with complex objects. Basically, such an assessment is conducted on the basis of actions' protocol or


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visual observation. However, in the case of a large number of trainees and a limited number of experts, this method cannot be used. The task is to automatically evaluate trainees' actions and form the necessary recommendations.

The trainee's recommendation is designed to improve his/her activities' effectiveness when he/she is working with real equipment. In order to increase the efficiency, the authors propose to form competences aimed at solving the following tasks:

- to reduce the equipment's failure probability because of trainee's incorrect actions;
- to optimize the actions' sequence in work task performance in order to shorten time;
- to eliminate uncertainty when planning actions' sequence to perform a work task;
- to reduce the discrepancy between the expected and real behavior of an equipment.

The task of trainees' actions assessment in simulation systems and virtual worlds is considered to be poor-structured. The knowledge of recommendations' formation is mainly heuristic and uncertain, and depends on the expert's experience. At present, there are no formal methods for recommendations' formation. A similar area is a good application area for expert systems. When developing an expert system, it is necessary to define methods for acquiring knowledge, presenting knowledge, facts, and the logical conclusion [10].

The goals of this research work are: to develop a mathematical model of a virtual laboratory, which includes a complex of computer-based simulation systems of measuring devices; to develop a method of trainee's actions assessment in a virtual laboratory; to realize and integrate a virtual laboratory into the learning process.

## 3 Overview

The task is suitable for several classes of expert systems.

1. Diagnostic systems are designed to detect faults' sources based on observations of the controlled (technical or biological) system's behavior. Diagnostics is the process of object correlation with an object class and/or fault detection in some systems. A fault is a deviation from the norm. An important feature is the need to understand the functional structure of a diagnosable system. EMYCIN [6], ESMDA [7], VIBEX [8] are expert systems.
2. Monitoring systems analyze the behavior of a controlled system and predict the probability of the goal achievement, comparing the obtained data with the critical points of the pre-compiled plan. The main task of monitoring is continuous interpretation of data in real time and signaling about the exit of a parameter beyond acceptable limits. The main problems relate to the missing of an alarming situation and the inverse task of "false" positive. The complexity of these problems is concerned with the vague of alarming situations' symptoms and the need of the temporal context accounting.

## 4 Simulation System's Model

The authors consider simulator as a set of input and output controllers. Each input controller (sensor) has several processed events. When an event occurs, the sensor indicates that the simulator's internal state is changing. The simulator's state monitoring is possible only through external controllers (indicators), each of which can be in a certain state.

Therefore, the simulator is given as:

$$\text{TRAIN} = (\text{SENSOR}, \text{SENSOR\_TYPE}, \text{IND}, \text{IND\_TYPE}, \text{S}, \text{S0}, \text{JUMP}, \text{OUTPUT}), \quad (1)$$

where SENSOR is a set of input controllers,

SENSOR_TYPE is a set of processed events,

IND is a set of output controllers,

IND_TYPE is a set of output controllers' states,

S is a set of simulator's internal states,

S0 is a simulator's initial state,

JUMP is a transition function between the simulator's states under the event's action on an input controller, $S \times SENSOR \times SENSOR\_TYPE \rightarrow S$,

OUTPUT is an output function, $S \rightarrow \{IND, IND\_TYPE\}$.

Let us assume that the simulator changes its state only after the input controllers affect it. It should be noted that the values of S, S0, JUMP, OUTPUT are unknown for the action analysis system.

A trainee has an action upon the simulator through sensors or objects. The authors define actions as A, A = (SENSOR, SENSOR_TYPE). In the process of work, A trainee generates a sequence of actions during his/her work. An action's sequence is defined as L. The authors designate the states as STATE, STATE = (IND, INT_TYPE). Let us assume that the state of the system depends only on the sequence L.

## 5 Classification of Recommendations

A recommendation is a prompt text that helps a trainee to achieve his/her goal with fewer steps. A given goal is a set of certain states of output controllers. The goal can be explicitly given (the goal of training, control points, etc.) or automatically formed based on a trainee's action history analysis. Consider the classification of recommendations.

***Recommendations when a goal is not achieved***

A trainee fails to achieve any specific goal from the current system's state. As an example, if a trainee led the simulator or the virtual world object to failure, the following recommendation occurs: "You broke the device by setting the voltage at 100 V. The maximum allowable voltage is 20 V". It is shown in Fig. 1.

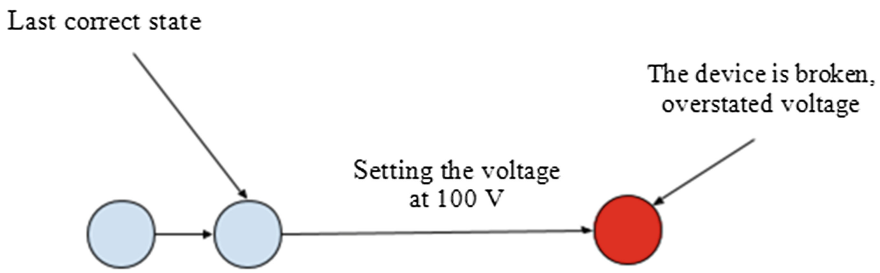


**Fig. 1.** Recommendation "You broke the device by setting the voltage at 100 V. The maximum allowable voltage is 20 V"

***Recommendations when a certain goal is achieved***

In order to achieve the current system's state, there is a more effective sequence of actions. The recommendation "You can skip 2 steps if you set the voltage using a new value input instead of bitwise change" is shown in Fig. 2.

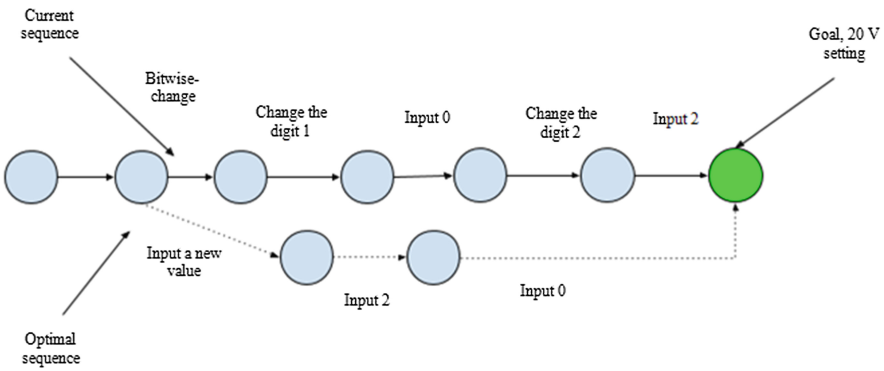


**Fig. 2.** Recommendation "You can skip 2 steps if you set the voltage using a new value input instead of bitwise change"

***Recommendations when a trainee has potential goals***

This type of recommendation helps trainees to complete a task. It allows a trainee to reduce the uncertainty in planning the action's sequence for the work task performance as well as explain a trainee why his/her actions fail to achieve the expected result. The recommendation "You cannot solder without a soldering iron. If you want to solder a part, take the soldering iron in your hand" is shown in Fig. 3.

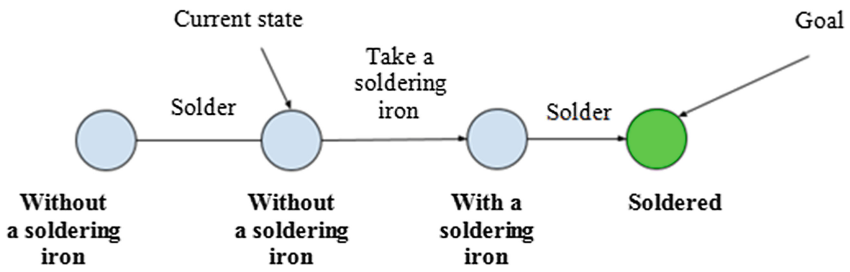


**Fig. 3.** The recommendation "You cannot solder without a soldering iron. If you want to solder the part, take a soldering iron in your hand"

## 6 Rules

The action analysis system reads the virtual workplace after each trainee's action. Readings include:

- an interaction object, a controller into the simulator;
- a type of interaction;
- a set of objects' states, into which the system has passed.

The reading's model is given as:

$$\text{SNAPSHOT} = (\text{OBJECT}, \text{ ACTION}, \text{ STATE}), \tag{2}$$

where OBJECT is an interaction object,
ACTION is a type of interaction,
STATE is a new state of the system.

Each new reading enters the expert system and forms a reading's sequence. In order to access a specific reading, the term snap is introduced, snap = N → SNAPSHOT, the argument of which is the offset number relative to the last reading.

In order to assess trainees' actions the authors use direct inductive inference.

The authors propose to consider some rules for the recommendation's formation.

***You cannot solder without a soldering iron. If you want to solder a part, take a soldering iron in your hand*.**

The rule is defined as:

$$\begin{aligned} &snap(0).object\_action = \text{'}soldering\text{'} \;\&\&\; snap(0).state.hand <> \text{'}soldering\ iron\text{'} \\ &\;\; => puts\ \text{''}You\ cannot\ solder\ without\ a\ soldering\ iron.\ If\ you\ want\ to\ solder\ a\ part, \\ &take\ a\ soldering\ iron\ in\ your\ hand\text{''}. \end{aligned} \tag{3}$$

***You can skip 2 steps if you set the voltage using a new value input instead of bitwise change*.**

The rule is:

$$snap\,(-6)\,.object\ =\ '5'\ \&\&\ snap\,(-6)\,.action\ =\ 'click'\ \&\&\ snap\,(-6)\,.state.shiftUp\ = \\ true\ \&\&\ snap\,(-6)\,.object\ ==\ '1'\ \&\&\ snap\,(-5)\,.object\ ==\ '1'\ \&\&\ snap\,(-3)\,.object \\ ==\ '2'\ \&\&\ snap\,(-1)\,.object\ ==\ '3'\ =>\ puts\,'\ \ldots' \tag{4}$$

***Turn on the power before using the device.***
The rule is defined as:

$$snap\,(0)\,.object\ <>\ 'power'\ \&\&\ snap\,(0)\,.state.power\ =\ false\ =>\ puts\,'\ \ldots' \tag{5}$$

***You set the signal parameters of the device, but you have not started it up.***
The rule is defined as:

$$Snap\,(?x).\,State.shiftUp\ =\ false\ \&\&\ snap\,(?x)\,.object\ =\ ''0''\ \ldots\ ''9''\ =>\ goal\ =\ 'Start \\ signal\,up',\ last\_goal\ =\ ?x \tag{6}$$

$$?y\ <\ last\_goal\ \&\&\ (snap\,(?y)\,.ExternalPulsePos\ =\ true \| snap\,(?y). \\ ExternalPulseNeg\ =\ true\ \|\ snap(?y).\,OuterPulsePos\ =\ true \| snap\,(?y). \\ OuterPulseNeg\ =\ true)\ =>\ Mode\ =\ true \tag{7}$$

$$Goal\ =\ ''Set\,mode\,up''\ \&\&\ mode\ <>\ true\ \&\&\ snap\,(0)\,..\,object\ =\ ''power''\ =>\ puts\,''\ \ldots'' \tag{8}$$

The automaton for recommendation's formation is shown in Fig. 4.

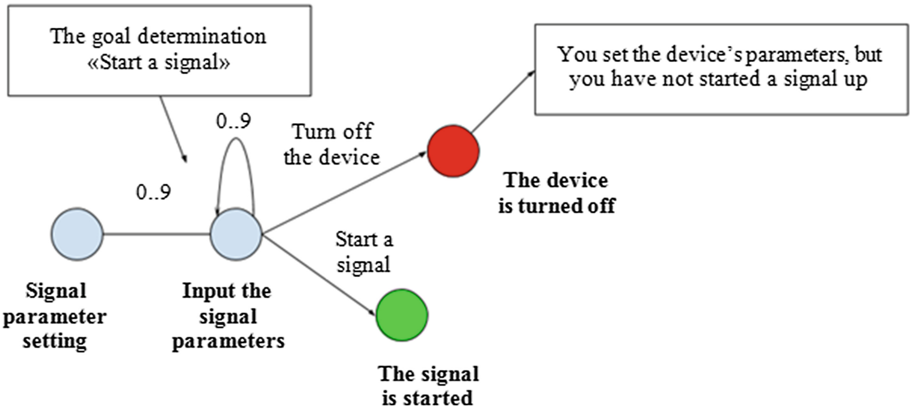


**Fig. 4.** Rules for the recommendation "You set the parameters of the device, but you have not started the signal up"

At the initial stage, knowledge acquisition is carried out through the knowledge extraction, by interviewing domain experts and manually converting knowledge into a set of generative rules. In future, an automatic analysis of the experts' actions when working with simulators is proposed. This analysis allows the system to form individual work cards, as well as fill the knowledge base. But then an interaction problem of several knowledge sources becomes.

## 7 Realization

On basis of the proposed model and method the virtual laboratory is implemented at C#, simulating the work of 20 measuring devices (generators, digital voltmeters, multipurpose instruments, and etc.) Each virtual device simulator has 4 modes: “Help”, “Emulation”, “Exercise” and “Control”.

The HELP mode provides text comments on the purposes of control bodies/units/blocks, screens, indicators and external connectors.

The EMULATION mode is used to simulate an operation of a device.

In the EXERCISE mode a trainee is given a (solved) task and its step-by-step execution with comments.

In the CONTROL mode a trainee is given a task.

In the EXERCISE and CONTROL modes the subsystem of trainee’s actions analysis is functioning, forming a list of errors and recommendations for their correction.

For a rank of measuring instruments the base of circuit’s objects was designed, which includes the electronic circuits connected to virtual devices. This enables to conduct measuring experiments. This simulation system is used for training university students in such specialties as Radio Engineering, Informatics & Computer Science, Telecommunications, as well as for professional upgrading of companies’ employees. Undergraduate students are involved in the development of VL components.

## 8 Conclusion

In order to solve the problem of automatic trainees’ actions assessment when working with simulators and virtual worlds, it is proposed to use the rule-based production expert system. The knowledge acquisition is carried out through the knowledge extraction by interviewing domain experts and manually converting knowledge into a set of generative rules. The facts are presented as a set of snapshots of system’s states after each trainee’s action, including the interaction object, the type of interaction and a new state of the system. Recommendations are formed on basis of direct inductive inference.

The further direction of the research work is automatic knowledge generation on the basis of the experts’ actions analysis.

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## References

1. Afanasyev, A.N., Voit, N.N., Kanev, D.S., Gulshin, V.A.: Modeling of virtual simulators based on automata approach. Radio Eng. **6**, 55–58 (2015)
2. Afanasyev, A.N., Voit, N.N., Kanev, D.S.: The development and analysis method and the model of computer simulator. Autom. Control Process. **2**(40), 64–71 (2015)

3. Afanasyev, A.N., Voit, N.N., Gulshin, V.A., Bochkov, S.I.: Industrial virtual worlds designing at OpenSim. Bull. Ulyanovsk State Tech. Univ. (Bull. UlSTU) **1**(77), 42–46 (2016)
4. Voit, N.N., Molotov, R.S.: Training simulator of the military range. In: Toloka, M.A.V. (ed.) Systems of Design, Engineering Preproduction and Management of an Industrial Product's Life Cycle Stages (CAD/CAM/PDM - 2016), Proceedings of the 16th International Youth Conference, Analytical LLC, p. 30 (2016)
5. Afanasyev, A.N., Voit, N.N.: Development of the component-service training platform: diagrams of classes of the program component of the script in UML-language. Bull. Ulyanovsk State Tech. Univ. **2**(58), 32–36 (2012)
6. Voit, N.N.: Development of methods and means of adaptive management of the learning process in the automated design. Ph.D. thesis in Engineering Sciences/Ulyanovsk State Technical University, Ulyanovsk (2009)
7. Afanasyev, A.N., Voit, N.N.: Development of a component-service training platform: analysis and development of a component of the method for diagnosing of design characteristics of a trained engineer using UML diagrams. Bull. Ulyanovsk State Tech. Univ. **4**(60), 43–46 (2012)
8. Afanasyev, A.N., Voit, N.N.: Development of methods for fuzzy parametric adaptive diagnostics of a trained engineer. Autom. Control Process. **3**, 51–56 (2009)
9. Afanasyev, A.N., Voit, N.N.: Development and research of the extraction tools from CAD KOMPAS-3D and representations in web-systems of design description, 3D models of industrial parts and assemblies. In: Toloka, A.V. (ed.) Proceedings: Systems of Design, Technological Preparation of Production and Management of an Industrial Product's Life Cycle Stages (CAD/CAM/PDM - 2015), Proceedings of the International Conference, pp. 208–212 (2015)
10. Jarratano, D., Riley, G.: Expert Systems: Principles of Development and Programming, 4th edn. Williams Publishing House (2007)
11. Shortliffe, E. (ed.): Computer-Based Medical Consultations: MYCIN, vol. 2. Elsevier (2012)
12. Naser, S.A., et al.: Knowledge management in ESMDA: expert system for medical diagnostic assistance. AIML J. **10**(1), 31–40 (2010)
13. Yang, B.S., Lim, D.S., Tan, A.C.: VIBEX: an expert system for vibration fault diagnosis of rotating machinery using decision tree and decision table. Expert Syst. Appl. **28**(4), 735–742 (2005)

# 20 Years of Co-creation Using Case Based Learning

## An Integrated Approach for Teaching Innovation and Research in Product Generation Engineering

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**Abstract.** The teaching program *IP - Integrated Product Development* has been implemented annually with great success for 20 years, which means that this format has gained a high level of acceptance among companies from a wide range of industries. The participating students acquire professional skills in the area of *PGE - Product Generation Engineering* through the experience of the real development project and by applying activities and methods of product development, combined with a lecture that deals with the most recent cases from the business world. With the aim of bringing the co-creation formats to further student target groups with diverse needs, the format *IP* was analyzed and a general valid co-creation approach for case-based learning, was characterized by relevant success factors. Based on this, it was possible to transfer the success factors from *IP* contextual into the breadth (reaching a high number of students) and into the depth (gain of research competences) by means of two further formats.

**Keywords:** Professional skills · Case-based learning · Co-creation

## 1 Motivation and Goal

As academic teaching of engineers has the responsible position to educate the next generation of product developers it must react to different trends without sacrificing proven concepts of teaching. Even if teaching accepts future employability and transmission of professional skills as its major goals it must keep in mind that this does not mean to follow each and every industry trend down to the finest detail. It rather should concentrate on enabling students for lifelong learning in their fields of expertise as well as on enabling them for interdisciplinary collaboration. Lifelong learning includes teaching students to solve discipline-specific problems while choosing and using appropriate methods. Furthermore, it also includes teaching them to understand the structure of a problem, to recognize a lack of knowledge on their side and to show them how to overcome it. Thus, teaching must enable students to solve modeling problems, to choose and apply appropriate methods, to generate and follow intelligent


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processes and to learn and operate new tools. Hence, a teaching format should go further than imparting knowledge and especially support the acquisition of expertise. The actual development of expertise emerges from the application of acquired knowledge to new and unknown problems, which means that the profession-oriented skills of an expert can only be developed through performing specific tasks in a case based environment. Since 1996 the *KaLeP- Karlsruhe teaching model for product development* aims at supporting the development of expertise. It includes the triad between lecture, exercises and projects as supplementary elements [1]. As the teaching flagship the course *IP - Integrated Product Development* [2, 3] has made use of this approach for more than 20 years. There exist a lot of approaches, concepts and projects in engineering teaching which cover some of the aspects mentioned above, especially when it comes to getting in touch with industrial companies in academic teaching. The existing approaches in this field, however, are often limited to guest lectures, short term interaction or cooperation in projects in which the main goal is the acquisition of students as future employees. Real co-creation in the sense that the project goal focusses on the usage of project results on the market for real customers does almost not appear at all. This is also the reason why existing product development challenges in engineering teaching haven't been used as research environment for new methods, processes and tools of *PGE - Product Generation Engineering*, which means the development of products in generations, referring to reference products [4]. As long as students are not fully convinced of the success of the project and do not believe in the later utilization of their results of a marketable product or service, they will not be able to provide realistic and serious feedback. Particularly when it comes to evaluating new methods, processes and tools of *PGE*, which helped them, reach their project goals. This leaves the huge and highly relevant potential of co-creation projects in academic teaching, as research environment in the sense of a Live-Lab, widely unused.

## 2 State of the Art

### 2.1 Practical Oriented Engineering Education Using the Live-Lab Approach

The increasing complexity of technical products, which, among other things, is the result of the megatrends of the connectivity and individualisation of the society [5] leads to the fact that current and future product generations are subject to an increasingly strong interdependence of the domains of mechanical engineering, electrical engineering and information technology. Therefor the goal of university education cannot be to enable students to gain competence in all disciplines, but to convey a lot more problem-solving and professional skills, in order to encourage a situation-oriented operation [6]. The development of these competences is only possible through an adequate practical link in teaching. This practical reference means that by carrying out various activities and then reflecting on them, the students are able to gain their own experiences and thus acquire professional skills. According to the *KaLeP* [7] competence is gained through the combination of teaching (knowledge generation), tutorials (knowledge consolidation) and projects (knowledge transfer and reflection). For competence acquisition, it is not sufficient to teach methods and processes without referring to a system. Instead, all aspects should be combined: methods, process and system teaching [8]. Straight practice in the course of the study usually takes place far away from the transfer of knowledge and reflection, as a result of which no competence is gained at the worst. Furthermore, university teaching should have an additional focus on research competence [9]. Research of methods, processes and tools in *PGE* and innovation management often lacks usefulness of its results for practical implementation into companies. One main reason for this might be that new methods, processes and tools are developed within a more academic environment and evaluated within straight laboratory studies if at all. These evaluation results are in most cases too generic to be adapted to practical use. On the other hand, there exist field studies which evaluate the use of methods, processes and tools within one single company or division. The results of these studies are often too specific to transfer them sustainable into other companies. Consequently, there exists a gap between laboratory studies and field studies concerning methods, processes and tools in *PGE*. One possibility to close this gap are so-called Live-Labs. A Live-Lab in the context of *PGE* is a research environment, which enables research about methods, processes and tools within a preferably realistic *PGE* process with the possibility to shape and control the boundary conditions to a high degree. Within Live-Labs, suitable subjects, for example students of engineering study courses, work on real *PGE* challenges provided by a partner company. During the *PGE* project, they use different methods, processes and tools (for example methods of creativity and methods of evaluation, scrum or innovation platforms) which are researched through suitable forms of data collection. Thus, different aspects like the quality of methods, how methods were accepted and socio-technical effects can be examined. For the subjects the character of the project is in the foreground they consider themselves not as subjects but as product developers and evaluate methods, processes and tools not from a theoretical point of view like in laboratory studies but from a project point of view. This is why they act more natural than in laboratory studies [10].

## 2.2 Co-creation Over 20 Years

Manufacturing companies have turned closer and closer to customers and their specific needs over the past six decades. This lead to various concepts of user-centered design, which include “the user” or “the customer” to a different degree respectively [11]. Examples are lead-user innovation and usability testing. All these concepts concentrate on few activities of the design process and only on those activities, which take place before or after the actual product design. In contrast, co-creation is about joint creation of value by the company and the customer [12]. This relates to topics like defining a problem, but in the very core of co-creation also to the co-construction of the product or service in question. In this sense, the traditional understanding of markets in which companies produce value propositions which are merely consumed by customers and in which ‘the customer is always right’ is accepted as an eternal paradigm. Moreover it is extended into an understanding of collaboration on an at least partly level playing field [13]. The customer, who is traditionally seen as positioned outside of the domain of the value chain, becomes an integral part of the system for value creation [14]. Apart from the co-creation readiness of the company, the degree to which co-creation is really conducted, depends also very much on the expertise, passion and creativity of the customers [11]. Furthermore, there exist a variety of success factors and key strategies, which support the implementation of successful co-creation. Most of them concentrate on the appreciation of the customers' direct experiences and their seamless integration into suitable activities. For example, the limited technical experience of the customer within a specific branch is not seen as barrier but as a trigger for creative thinking, preventing self-censorship which often appears when experienced developers face a supposedly unsolvable technical problem [15]. As transfer of the co-creation approach into practice the lecture *IP* is based on to the eponymous design approach of Ehrlenspiel [16]. The format developed by Albers [7] was implemented in 1997 since then, the project is carried out annually in the winter semester. Beside lectures and workshops the project work is the third pillar of the main subject *IP*. In this project the aim of the students is the development of new products, based on development tasks of real project partner companies. The spectrum of the problems reached from "age mobility in the everyday life" about "innovative battery concepts for electric vehicles" up to "gardening tools of tomorrow". Thereby focus lies, on this occasion, on the development of prototypes with high innovation potential.

In *IP*, 42 students develop products following a *PGE* processes with five phases (according to Fig. 1) starting with an initial analysis of reference products on the market and the state of the art (1) to the identification of market potentials (2) and the generation of product ideas (3) to the development of concepts (4) and final prototypes (5). For this they work in teams in two large rooms which they have exclusively at their disposal, including seven work islands. In all phases they use a wide variety of different processes, methods and tools which they adapt to their situation to ensure project success. Every project phase starts with a kick-off and ends with a milestone with participation of the project partner. This guarantees seriousness which is indispensable to motivate students to convert simple knowledge which they acquire in lectures and exercises into professional skills. During the past 20 years, success factors for co-creation processes of companies, students and universities, dependent on the situation, were derived by the observation of the project *IP*.

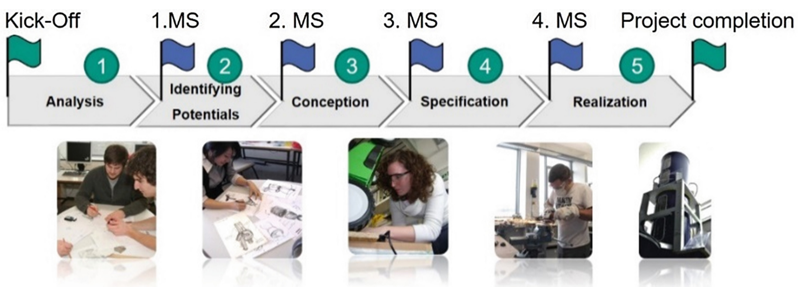


**Fig. 1.** The process of IP – Integrated Product Development

## 3 Research Methodology and Research Questions

*IP* is a teaching concept that addresses teaching innovation and research in *PGE* but it entails two limits: (1) due to limited resources it can only be offered to 42 students. (2) It concentrates on the development of new product generations. In terms of the Live-Lab, it is up to the teachers to investigate new methods and processes of *PGE*. This paper is therefore going to present two further lectures, which address the mentioned limitations. Initially the existing *IP* teaching concept is analyzed, followed by two deduced teaching formats. This leads to the following research question:

- How can students develop professional skills within co-creation projects like *IP* and which are success factors of such teaching approaches?
- How can the *IP* approach be transferred into a regular practical course for a large number of students using virtual collaboration?
- How can the *IP* approach be applied, to educate students as researchers in *PGE*?

To explore these research questions, the cooperation of university, students and companies according to practice-oriented teaching was examined, exemplified by the lecture *IP*. The approach of co-creation was further analyzed in terms of the three aspects teaching, research and innovation. As *IP* has been conducted on a yearly basis over the last 20 years it functions as initial point for the identification of success criteria, methods, process items, tools, best practices and reference processes for co-creation (see research question 1). The identified criteria were evaluated in a group consisting of four young scientists. In order to transfer the co-creation approach of *IP* to new teaching formats (see research question 2 and 3) various workshops have been conducted with scientists and companies, especially in the context of the EU project *Science2Society*. As a result, the two teaching formats *ProVIL – Product Development in a Virtual Idea Laboratory* and *AIL – Agile Innovation Lab* were developed and modeled. All the mentioned formats are combined under the IPEK co-creation Framework “ASD – Agile Systems Design”.

## 4 Success Factors for Good Practice-Oriented Teaching

Depending on different boundary conditions, the emphasis of the individual specific co-creation format varies. Key element of each format (*IP*, *ProVIL*, *AIL*) is the combination of lectures, exercises and the development project for which the industrial company provides the project assignment, to ensure realistic boundary conditions for the students. Co-creation with a company in combination with a structured *PGE* process functions as a main success factor. Further success factors in *IP* are for example the use and adaption of innovative development methods, e.g. customer interviews, customer journey videos or different methods of creativity. Furthermore, *IP* follows an accompanying prototyping approach encouraging the students to generate physical models in early phases to make the progress and the flow of information of development generations more efficient. Apart from this, students learn practically how to validate all partial results and the overall outcome of a product development process. As *IP* has been conducted for more than 20 years with industry partners from different sectors (from paper processing machines, via water pumping systems to the shaping of lorry cabins) the generalizability of the approach has been ensured. This forms the basis for the transfer of this approach to other universities and other teaching institutions. In Table 1 the various success factors of the ASD approach, which were identified on the basis of their characteristics in the retrospectively analyzed format *IP*, are shown.

**Table 1.** *IP*: Systems of Objectives (SoO) - related to students, institute and project partner and Operating system

| | | Success-factor | Description | IP |
|---|---|---|---|---|
| SoO students | innovation | Development result | Development of project results with high innovative potential | Generation of mature product concepts and prototypes, which partly lead to patents. |
| | | Company interaction | Interaction with the project partner | Interaction of the students with the project partner during the kick-off event and at the milestones. In addition: mentor concept of selected employees of the project partner with the teams or close cooperation with the project management team. |
| | | Networking I | Networking with project partner | Engaged students make close contacts with project partner. |
| | teaching | Teamwork | Striving for teamwork | A fixed component of the project format |
| | | Methodological competence | Acquiring methodological competence | To select and adapt methods according to the specific situation |
| | | Self-organization | Learning of independent and self-organized work | Teams are subject to defined guidelines, but plan resources and activities within the individual phases. |
| | | Research skills | Acquiring research skills | No research competencies are acquired. |
| | research | Thesis | Preparation of thesises | Project accompanying as an observational study |
| | | Networking II | Networking with the institute | Deepening contact with institute staff, first regard to future career. |
| | | Paper | Development of scientific paper | Accompanying |
| SoO institute | innovation | Project acquisition | Creation of further acquisitions for further projects | Show further possible project formats in close coordination between institute and partner. |
| | | Talent retention | Access to future employees | Actively addressing selected students in order to win them for selected master's courses (for example, as part of AIL). |
| | teaching | Dissemination of competences | Dissemination of methods, professional and research skills | Dissemination of method- and professional competences. |
| | | Leadership skills | Increase leadership skills among employees | Leading multiple teams |
| | | Reflection | Enabling the students to reflect what they have learned | Regular, partly guided, partly self-responsible reflection of the main project results, methods, processes, tools and social factors |
| | research | Research studies | Striven number of studies | 1 - 3 |
| | | Research focus | Striven focuse on studies | Methods, processes, tools for PGE. Focus on on-site collaboration |
| SoO partner | innovation | Open-innovation | Using of open-innovation potentials | Creation of an external environment in which a development theme is advanced. |
| | | Development horizon | Striven development horizon | Early phase of pre-development right up to one development generation away from the start of production |
| | | Knowledge acquisition | To acquire methodological / process knowledge | Project partners learn about the development methods used within the scope of the milestone presentations and through extensive discussions and participate in workshops developed by the students. |
| | | Project results | Usability of the project results | The project results are very well developed. However, major changes have to be made during the transfer to a further (serial) project (for example, Design for Manufacturing, etc.) |
| Operating system | | Selection criteria participants | | Application interviews - experience in the field of PGE provided |
| | | Team composition | | 7 teams with 6 students each |
| | | Measures of teambuilding | | Kick-off event, regular smaller team events - barbecue, bowling. |
| | | Working atmosphere in the team | | Usually very good team spirit due to close, daily cooperation |
| | | Diversity of team roles | | 6 predefined roles, which are fixed by the students in the team in their own responsibility for the duration of the project |
| | | Identification with team success | | Extremely high → Competitive atmosphere with other teams and high recognition by the project partner |
| | | Working effort | | High, after milestones, workload is briefly reduced |
| | | Number of supervisors | | 3 |
| | | Available infrastructure | | 2 working rooms, method box, 42 computers, prototype development centre, 1 creativity lab |
| | | Development budget | | ~ 2.000,-€ |

Relevant success factors were categorized by means of the systems of objectives [17] of the various interacting stakeholders and the operation system [18, 19]. As different stakeholders pursue different objectives within the ASD approach, the systems of objectives, in which some of the success factors can be categorized, have been set up in a stakeholder-specific manner. The operation system consists of all stakeholders involved in the project as well as available knowledge, infrastructure and resources. In addition to the success factors, a description of these factors is given as well as the *IP*-specific characteristics of each factor. However, the analysis of the format *IP* shows, that this student development project is aimed at only a very specific, limited target group of students - at students who want to train themselves as product developers. On the one hand, there is a need to bring the methodology of *PGE* closer to a larger group and, on the other hand, to educate researchers in the *PGE*, which could forward the development of innovation methods and processes as future academic researchers. For this reason, the project formats *ProVIL* and *AIL* were developed on the basis of a variety of the identified success factors.

## 5 Transfer of the Results into Further Projects

The formats *ProVIL* and *AIL* newly generated on the basis of the success factors address additional target groups. In Table 2 the ASD formats are compared by means of superordinate factors.

**Table 2.** Comparison of formats based on overlapping factors

| Successfactor | | ProVIL | IP | AIL |
|---|---|---|---|---|
| Focus | | application of methods | selection and adaptation of method | methods research |
| Number of participiants | | 48 (target ~200) | 42 | 4-6 |
| ECTS | | 4 | 16 | 30 |
| Ideally, previously viewed formats | | MKL | MKL, ProVIL, PGE - MPI | MKL, ProVIL, PGE – MPI, IP |
| Forms of collaboration | | Cross-site, virtual | On site | On and cross site |
| Previous knowledge of students | In area of specific competence | 2 out of 5 | 4 out of 5 | 4 out of 5 |
| | In area of methods competence | 0 out of 5 | 2 out of 5 | 5 out of 5 |
| | In area of social competence | 2 out of 5 | 2 out of 5 | 5 out of 5 |
| | In area of creativity | 0 out of 5 | 2 out of 5 | 4 out of 5 |
| | In area of elaboration skills | 1 out of 5 | 3 out of 5 | 5 out of 5 |

Since *ProVIL* addresses the majority of students, methods of development are predetermined in all phases during the *PGE* process, so that the students do not carry out the selection and adaptation of the methods. Based on the large attendance the necessary close supervision cannot be exercised. Nevertheless, the students are learning the first usage of methods on the basis of the real development project, but have less previous knowledge of the methodology compared to the participants in *IP*. Moreover, the project work takes place in the virtual space due to the high number of participants. *AIL* was conceptualized with the aim of amplifying the co-creation approach and consequently expanding the professional skills acquired in *IP* to gain research competences. In this format only one group of students is involved in the project work. In addition to this project work, the participants are also exploring and developing applied methods. The findings, which are generated from the real implementation of methods, are documented by the participants in their theses simultaneously with the project. The previous knowledge is significantly higher of those students who take part in *AIL* especially in the fields of expertise, methodological competence, social skills, creativity and elaboration. Based on the previously visited formats *MKL - mechanical design theory*, *ProVIL*, *PGE –MPI - product generation engineering - with methods and processes to innovation* and *IP* in comparison to those participants of *ProVIL* who have a vague idea about it, at best. The different efforts of the individual ASD formats justify a different allocation of ECTS points.

### 5.1 ProVIL: Co-creation for the Many

To allow for a larger number of students (up to 200 per year) to experience the co-creation approach of *IP*, *ProVIL* has been developed. In Table 3 the different forms of each success factor in the specific context of *ProVIL* are visualized.

In contrast to *IP*, *ProVIL* follows only the first four phases and requires less time effort for the students (4 ECTS compared to 16 ECTS in *IP*). Within *ProVIL*, the students work partly together in teams from different locations [20]. For this, they use an online innovation platform, which contains the exact structure of the development process and templates, documents, training videos of *PGE* methods and task descriptions (Fig. 2).

In this respect, the process of *ProVIL* is much more pre-structured compared to *IP* allowing a broad range of students to apply methods, processes and tools in *PGE* without having to adapt the provided methods. As students in *ProVIL* do not regularly meet at one place, innovation coaches support them as moderators and process facilitators. The interaction with the project partners takes place at meetings like the kickoff and the project closeout. Apart from this, some of the phase milestones are organized as web conferences. Co-creation in *ProVIL* takes place in two different ways. Firstly, the

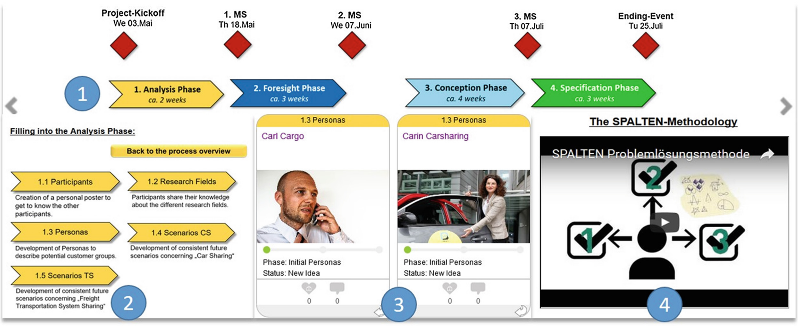


**Fig. 2.** (1) Process overview on innovation platform, (2) analysis phase, (3) idea cards representing results of Persona method, (4) teaching video

**Table 3.** Forms of the success factors in *ProVIL*

| | | Successfactor | ProVIL |
|---|---|---|---|
| SoO students | innovation | Development result | Generation of product concepts including prototypes, which however are relatively far from the start of production |
| | | Company interaction | Interaction of students with project partner virtually via innovation platform (in particular via feedback and idea evaluation) and personally at the kick-off event and the milestones. |
| | | Networking I | The direct contact between students and project partners is rather loose. Only a few students build closer personal contacts to the project partner on the basis of their own efforts. |
| | teaching | Teamwork | A fixed component of the project format |
| | | Methodological competence | Use pre-defined development methods |
| | | Self-organization | Processing fixed toDos. Coordination of communication with the team |
| | | Research skills | No research competencies are acquired. |
| | re-search | Thesis | Project accompanying as an observational study |
| | | Networking II | First personal contact with institute staff |
| | | Paper | Accompanying |
| SoO institute | innovation | Project acquisition | Close coordination between institute and project partner. Show further possible project formats. |
| | | Talent retention | Optional identification of possible future employees. Joint discussion about possible perspective |
| | teaching | Dissemination of competences | First methods are taught |
| | | Leadership skills | Managing a project in the size of a department, comparable to middle management. Leading through processes and strongly formalized procedure. Run a project in virtual space. |
| | | Reflection | Guided reflection of selected project results, methods, processes and tools at given times. |
| | re-search | Research studies | 2 - 5 |
| | | Research focus | Methods, processes, tools of PGE. Focus on cross-site cooperation |
| SoO partner | innovation | Open-innovation | Creation of an external environment in which a development theme is advanced. |
| | | Development horizon | Early phase of pre-development |
| | | Knowledge acquisition | Project partner learns about the development methods used and their application in virtual space on an innovation platform through observation or active participation. |
| | | Project results | The project results are considered as exploratory. The usability of the project results depends strongly on the contributions of the project partner to the innovation platform. The effort to turn the project results into a further project is relatively high, since essential assumptions are secured and the student's work has to be intensified. |
| Operating system | | Selection criteria participants | No selection (First come, first served) |
| | | Team composition | 8 teams with 6 students each. In this case, 2 students each form a fixed two-team, so that a team consists of 3 tandems. |
| | | Measures of teambuilding | A large team at the beginning (Teambuilding workshop canoe building) and several smaller ones in the course of the project (barbecue) |
| | | Working atmosphere in the team | Very different and strongly dependent on the commitment of individual participants as well as the commitment of the respective Inno coaches. |
| | | Diversity of team roles | No fixed rolls. 3 focus topics in each project phase. Assignment of the tandems to focus topics by the students in their own responsibility. |
| | | Identification with team success | High to very high - strongly dependent on the commitment of the students. |
| | | Working effort | Average |
| | | Number of supervisors | 2 |
| | | Available infrastructure | Innovation-Plattform, Tablets |
| | | Development budget | 0,-€ |

*ProVIL* students co-create with members of the project partner on the innovation platform. While the students work on their tasks, members of the project partner can evaluate ideas and provide feedback to actual results. Secondly, the students also include further stakeholders into their project. For this, they conduct interview studies, online surveys and integrate other students and peers from their private network into the evaluation.

## 5.2 AIL: Co-creation with Focus on Research

In contrast to *ProVIL*, the 2017 introduced format *AIL* with 30 ECTS addresses a small group of students which are deeply interested not only in applying or adapting

**Table 4.** Forms of the success factors in *AIL*

| | | Successfactor | AIL |
|---|---|---|---|
| OS students | innovation | Development result | Generation of mature product concepts and prototypes, which partly lead to patents. |
| | | Company interaction | Interaction of all students with all members of project team and with clients of project partner. |
| | | Networking I | As a permanent project component, all students make close contacts with the project partner. |
| | teching | Methodological competence | A fixed component of the project format |
| | | Self-organization | Ability to select, adapt, develop, research and validate methods and tools. |
| | | Research skills | Guidelines are vague. Students design the process in self-organized and self-responsible manner. |
| | re-search | Thesis | Research competencies are acquired, thereby enabling students to carry out scientific studies |
| | | Networking II | A fixed component of the project format. Project accompanying as participatory study |
| | | Paper | Close cooperation with the Institute's staff. Joint, strategic orientation of thesis work. |
| OS institute | innovation | Project acquisition | Close coordination between institute and project partner. Show further possible project formats. |
| | | Talent retention | Involvement of selected students in institute courses with the explicit goal of hiring them as employees |
| | teaching | Dissemination of competences | Methods, professional and research competencies are taught |
| | | Leadership skills | Turn participants successful into product developers as well as researchers. |
| | | Reflection | Continuous, self-responsible reflection on project results, methods, processes, tools and social factors |
| | re-search | Research studies | 6 - 12 (one per student) |
| | | Research focus | Methods, processes and tools for PGE for on-site collaboration as well as for cross-site collaboration. Studies are carried out on the basis of the system to be developed with the aid of resources of the project partner. |
| OS partner | innovation | Open-innovation | Creation of an external environment in which a development theme is advanced. |
| | | Development horizon | Closer to the series, right up to series-production development |
| | | Knowledge acquisition | Project partner learns about the methods of development used through continuous collaboration with students. The project partner directly provides the research results on the methods, processes and tools used in the project from the Master's thesis. Project partner participates in workshops developed by the students. |
| | | Project results | The project results are planned as an elementary part of further product development from the very beginning. The usability is very good thanks to the close cooperation with the project partner. The expenses for transferring the project results into a further project are low. |
| Operating system | | Selection criteria participants | Job interviews - professional competences in the field of PGE provided |
| | | Team composition | 1 team with 6 students |
| | | Measures of teambuilding | Kick-off event, regular smaller teamevents - grilling, bowling |
| | | Working atmosphere in the team | Usually very good team spirit due to close, daily collaboration. |
| | | Diversity of team roles | There is no fixed roll allocation, however, the students take different perspectives on the duration of the project through the selection of the thesis |
| | | Identification with team success | Extremely high -> high recognition by the project partner and involvement of the partner in activities designed by the students |
| | | Working effort | Very high, calmer phases in the development project are used to advance research work |
| | | Number of supervisors | 2 |
| | | Available infrastructure | 1 workingroom, method box, 6 computers, prototype development center, 1 creativity lab |
| | | Development budget | ~ 3.000,-€ |

**Fig. 3.** Students are generating (left) and evaluating (right) product profiles in *AIL*

methods, processes and tools of *PGE*, but to research them. Also in the project *AIL* the project partner gives one, for him relevant development task. Over several iterations, an ever more mature prototype of the later product is developed in coordination with the project partner. Due to the agile adjustments, the development process has a less strict interpretation. In this process, all three the process, the resource and the method application must be developed and planned by the students themselves. The institute's team acts only as consultant and coach. The students thus learn to develop methods and processes and to validate these directly on the basis of scientific principles on the system. Hence the format serves as a training for future method researchers and developers. This is why *AIL* is designed as a deeply focused Live-Lab environment with only six students in which the students play the double role of product and method developers.

While co-creating extremely narrowly with the project partner all students prepare their Master's thesis about a project-related but independent research subject. This way they are able to validate and refine methods of *PGE* within *AIL*. In Table 4 the stamping of the successful factors in the project format *AIL* are shown. In Fig. 3 you can see some participants of *AIL* during typical agile workshops.

## 6 Conclusion and Future Works

Within all of the ASD courses *IP*, *ProVIL* and *AIL* the students strive for a solution with high innovation potential which regularly leads to marketable patents. This provides the framework for the students to really acquire professional skills because they are highly motivated as they collaborate with a company on a product, which is of real relevance. Thus the three instances of the co-creation approach enable the students to apply for the first time methods of *PGE* during their 8th semester in *ProVIL* and refine and deepen them during *IP* in their 9th semester and further more conduct research in *AIL* within the scope of their Master's thesis. Hereby *ProVIL* provides a broad improvement of methodological expertise and skills of mechanical engineering of the students, whereas *AIL* increases the research competence for methodological questions.

## References

1. Albers, A., Burkardt, N.: Experiences with the new educational model "Integrated Product Development" at the University of Karlsruhe (1998)
2. Albers, A., Lohmeyer, Q., Alink, T.: On the importance of handling objectives in design education project work. In: International Conference on Engineering and Product Design Education, Trondheim, Norway (2010)
3. Albers, A., Burkardt, N., Deigendesch, T.: Vermittlung von Schlüsselqualifikationen am Beispiel des Karlsruher Lehrmodells für Produktentwicklung KaLeP. Schlüsselqualifikationen für Studium, Beruf und Gesellschaft. Technische Universitäten im Kontext der Kompetenzdiskussion, pp. 511–520 (2009)
4. Albers, A., Bursac, N., Wintergerst, E.: Product generation development – importance and challenges from a design research perspective. In: New Developments, Mechanics and Mechanical Engineering, pp. 16–21 (2015)

5. Groth, A.: Führungsstark im Wandel: Change Leadership für das mittlere Management. Campus Verlag (2016)
6. Matthiesen, S., Drechsler, S., Bruchmüller, T.: Universitäre Ausbildung zum Konstrukteur im Kontext des industriellen Wandels (2016)
7. Albers, A., Burkardt, N., Düser, T.: Competence-profile oriented education with the Karlsruhe Education Model for Product Development (KaLeP). World Trans. Eng. Technol. Educ. (WTE&TE) **5**, 271–274 (2006)
8. Breitschuh, J., Albers, A.: Teaching and testing in mechanical engineering. In: Vocational Education and Training: Research and Practice: Competence in Higher Education and the Working Environemnt, pp. 1–14. Peter Lang (2014)
9. Tremp, P., Hildbrand, T. (eds.): Forschungsorientiertes Studium – universitäre Lehre: Das «Zürcher Framework» zur Verknüpfung von Lehre und Forschung. Einführung in die Studiengangentwicklung (2012)
10. Walter, B., Albers, A., Haupt, F., Bursac, N.: Produktentwicklung im virtuellen Ideenlabor – Konzipierung und Implementierung eines Live-Lab, pp. 283–295
11. Sanders, E.B.-N., Stappers, P.J.: Co-creation and the new landscapes of design. CoDesign **4** (1), 5–18 (2008)
12. Design Factory Global Network: Design Factory Global Network. http://dfgn.org/. Accessed 14 June 2017
13. Prahalad, C.K., Ramaswamy, V.: Co-creation experiences: the next practice in value creation. J. Interact. Mark. **18**(3), 5–14 (2004)
14. Prahalad, C.K., Ramaswamy, V.: The co-creation connection. Strategy Bus. 50–60 (2002)
15. Kristensson, P., Matthing, J., Johansson, N.: Key strategies for the successful involvement of customers in the co-creation of new technology-based services. Int. J. Serv. Ind. Manag. **19** (4), 474–491 (2008)
16. Ehrlenspiel, K., Meerkamm, H.: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit, 5th edn. Carl Hanser Verlag, München (2013)
17. Albers, A., Klingler, S., Ebel, B.: Modelling systems of objectives in engineering design practice. In: International Conference on Engineering Design, ICED 2013. Sungkyunkwan University, Seoul, Korea (2013)
18. Albers, A., Reiß, N., Bursac, N., Richter, T.: iPeM – integrated product engineering model in context of product generation engineering. Procedia CIRP **50**, 100–105 (2016)
19. Ropohl, G. (ed.): Systemtechnik - Grundlagen und Anwendung: Einleitung in die Systemtechnik. Carl Hanser Verlag, München Wien (1975)
20. Albers, A., Bursac, N., Walter, B., Hahn, C., Schröder, J.: ProVIL – Produktentwicklung im virtuellen Ideenlabor. In: Entwerfen Entwickeln Erleben – Methoden und Werkzeuge in Produktentwicklung und Design 2016 (2016)

# Self-testing System Application to Remote Laboratory NetLab

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**Abstract.** Remote laboratories consist of a system of real equipment that can be operated over an internet connection by an offsite end user. However, their remoteness can make them inconvenient to maintain or repair should problems occur within the system. Self-testing systems can be used to detect possible problems and address them appropriately. With the aim of improvement, this paper considers the application of self-testing systems to remote laboratories. The paper starts with an investigative review of self-testing systems to highlight the key concepts and features within them. Following this is a discussion on the methodologies used by the self-testing systems. After which, observations are made of existing self-testing systems and how they are impacted by their own self-testing capabilities. Next, we consider the potential application of self-testing methodologies to a test case system, the remote laboratory NetLab, so as to theoretically demonstrate the practical application of integrating self-testing capability to an existing remote laboratory system. Finally, the paper forms a conclusion of self-testing system applications and their potential integration to remote laboratories.

**Keywords:** Self-testing · Self-healing · Remote laboratory · NetLab
Engineering education

## 1 Introduction

In this article, we would like to introduce the concept of using self-testing and self-healing systems with remote laboratories. Remote laboratories consist of a system of real, tangible equipment that can be operated remotely by an end user, typically through usage of an internet connection. With the advancement of internet technology, the use of remote laboratories will increase in the future especially in online delivery of courses where students have a limited access to laboratory equipment [1]. Remote laboratories offer a number of advantages over standard laboratories such as round-the-clock remote access, utilised independently of supervisory staff, no experimental danger to the end user, and efficient sharing of limited resources amongst many end users [2]. However, remote laboratories also have a number of weaknesses such as a dependence on the internet for access, lack of supervisory staff to address queries, and the need for maintenance and repair. Of these weaknesses maintenance and repair has the potential for the longest downtime since it


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must normally be done in person rather than remotely. This work can range from simply testing the equipment to check that it is operating within permissible parameters to completely dismantling the system to disconnect and replace faulty components. Comparing the time required for maintenance and repair between remote and standard laboratories is debatable since both equally depend on the end user or maintenance technician to detect and report system abnormalities before they can be further pursued for reparative investigation. However, unlike standard laboratories, remote laboratories generally have a requirement of continuous operation and accessibility to end users. Thus they will suffer the most from the impact of system downtime while waiting to be addressed by a technician, who is unlikely to be available outside office hours. If only there was a way to detect irregularities before an end user encounters them or if there was a means for the system to address the irregularities on its own.

Self-testing systems, as the name implies, are those that include the feature of being able to test its own system and to detect and diagnose potential problems therein [3]. This feature may be implemented through use of hardware, software, or some combination of the two. A self-testing system which includes both the ability to detect its own errors and the ability to mitigate them is often referred to as a self-healing system. The key advantage of such self-testing systems are effectively their capacity for round-the-clock autonomous monitoring and maintenance. This leads to faster responses to problem occurrences, reduced dependence on human administration, and increased system uptime. By incorporating self-testing systems, and by progression self-healing systems, into the designs of remote laboratories it is possible to compensate the weaknesses of remote laboratories.

## 2 Self-testing Systems

Incorporating self-testing functionality into a system is by no means easy and can become difficult for increasingly large or complex systems. Figure 1 illustrates the process of a self-testing system.

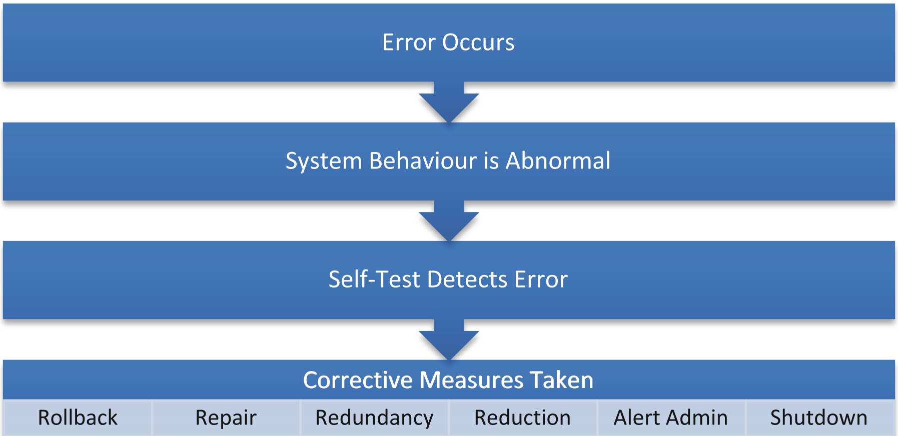


**Fig. 1.** Process of self-testing system with healing components

When designing self-testing systems, it is important to consider the granularity with which it will operate to ensure that it meets its purpose [3]. The degree of system granularity can range from individual components to various modules to whole sub-systems. The system may even cover numerous combinations of such degrees of granularity. Furthermore, the design process should consider the types of errors that the self-testing system will encounter so as to ensure that the system supports the capability to address them. One such example is to consider the errors by the classification of their duration, as shown in Table 1, and if the system has the capability to address them.

**Table 1.** Error types based on duration

| Duration | Description | Example |
|---|---|---|
| Permanent | Errors that remain consistent and continuous | A component has failed and produces no response |
| Intermittent | Errors that start and stop at (typically irregular) intervals | A component is prone to overheating. It will turn itself off when its temperature threshold is reached and will turn back on once it has cooled sufficiently |
| Transient | Temporary errors that gradually appear and disappear over time | A component is overly sensitive to light and its output characteristic alters based on the ambient illuminance |
| Runtime | Errors that only appear while the system is operating, but are not present during initial or idle states | During runtime a battery is connected to a resistor and light-emitting diode (LED) circuit. All individual components work correctly, but the battery's current is insufficient to illuminate the LED |

Another aspect to consider for self-testing systems is the intrusiveness of their methods of monitoring and detection. Although it may be desirable to continuously perform the complete set of self-tests on the system, this is not always practical since some tests may intrude upon the performance of the system's functions. With this in mind, it is advisable to develop a system schedule whereby non-intrusive tests can be run freely, but intrusive tests are limited to run at times of necessity or when system impact is minimal.

Although system self-testing is taken to mean the maintenance of system functionality in the presence of system problems, the enacted method of maintenance can be classified based on its type of implementation into categories [3], such as those given in Table 2.

**Table 2.** Methods of system healing

| Method | Description | Example |
|---|---|---|
| Rollback | When a problem occurs the system will reset (rollback) to an error-free state such as its default state or last known good configuration | For example, document writing software such as Microsoft Word typically includes an 'undo' feature which gives its user the ability to rollback changes made to the document |
| Repair | The system contains a method or mechanism capable of repairing faulty system aspects. It will attempt to apply a repair to the fault in order to restore the system structure to as near its original state as possible | For example, a conductive filament with magnetic properties can attract itself back together if it is broken or split in two |
| Redundancy | The system contains redundancy measures or spare components that can act as substitutes for ones which have faulted. When a problem does occur, the system will swap usage from the faulted aspect to a functional redundancy | For example, a system may contain duplicates of electronic components, such as resistors, so that if one should burn out then it can be effectively replaced by a spare |
| Reduction | In the event of a problem the system will disable the problematic aspect and its corresponding functions, but still continue to operate albeit with reduced functionality | For example, a system utilises a dual channel oscilloscope to observe voltage waveforms, but one channel ceases to function correctly. The system would respond by disabling that faulty channel while still allowing usage of the operational channel |

## 3 Case Study: FPGA Based Self-testing System

A case study on FPGA based self-testing system with healing methodology by [4] was investigated. Figure 2 shows the system-on-chip (SoC) model of the FPGA system and controller unit as it is connected by communication channels to individual components A, B, C, D, and an external memory module. During the design phase of the system each component (A, B, C, and D) is partitioned into sub-components (A1, A2, A3, B1, B2, etc…) and additional control circuitry is incorporated into each subcomponent to give it the ability to self-test for faults and to support healing methods. The external memory module is used to store the configuration bitstream I/O data and the sub-component data for components A, B, C, and D (i.e. A1, A2, A3, B1, B2, etc…).

The controller unit manages and controls the self-testing and healing methods for each component (A, B, C, and D). The controller unit utilises a two level hierarchical self-test method at both the component and sub-component level. At the first level, the controller unit performs self-tests at the component level by using a pseudo-random pattern generator to test input-output response of each component and detect faults. If a fault is found at the component-level, then the controller unit will proceed to the second-level and perform self-tests on each of the sub-components of the faulty

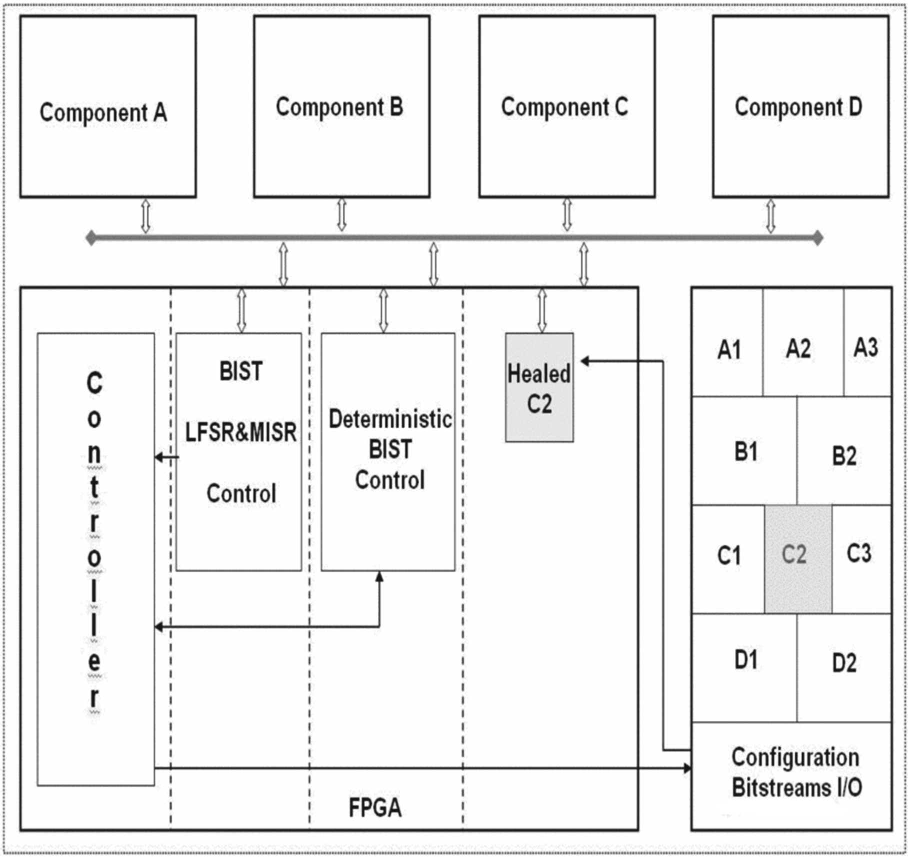


**Fig. 2.** FPGA self-testing system SoC architecture [4]

component. Through the use of deterministic testing on each sub-component partition it is possible for the system to identify any individual faulty partitions and 'mark' them as faulty with deterministic tags.

After having identified the faulty sub-components, the controller unit receives the deterministic tags from the component's control circuitry and begins the process of healing the fault. This procedure is shown in Fig. 3 and is done by transmitting a 'healing' signal to the external memory module that indexes the configuration memory and loads the configuration bitstream onto the FPGA. The FPGA is accordingly reconfigured to mimic the sub-component's functionality. The control unit then instructs the faulty sub-component's control circuitry to bypass the faulty module by rerouting its inputs and outputs to the replacement sub-component mimicked by the FPGA. The control unit then tests the performance characteristics of this FPGA sub-component and if it is satisfactory the control unit will resume normal operation. Otherwise, if the FPGA sub-component is unsatisfactory then the control unit will proceed to reiteratively reconfigure its synthesis parameters and reattempt the creation of the FPGA sub-component until it finally matches the original characteristics of the faulted sub-component. This process demonstrates the application of redundancy healing through the system's use of the FPGA as an adaptable form of redundancy, such that the single FPGA can be reconfigured to replace any sub-components in the event that they fault.

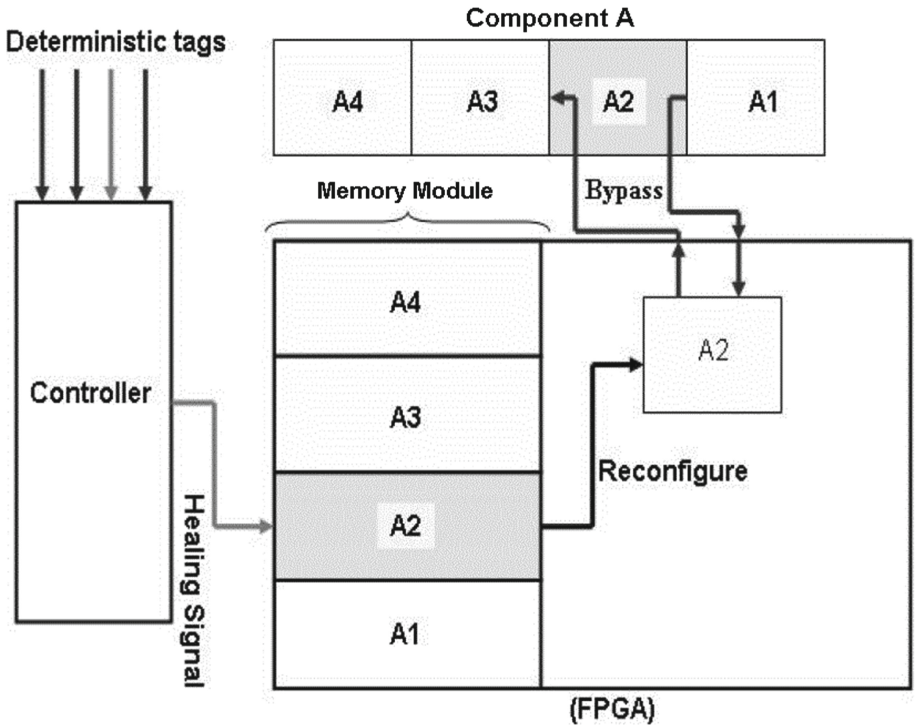


**Fig. 3.** FPGA based self-healing method [4]

This case study [4] also highlighted the potential cost savings of using this proposed FPGA system to embed self-testing logic at the design level as opposed to utilising high-cost Automatic Test Equipment (ATE) to perform equivalent testing on complex very-large-scale integration (VLSI) chips (e.g. components A, B, C, and D).

## 4 NetLab Architecture

The remote laboratory NetLab [5] was developed at the University of South Australia (UniSA) back in the year 2002 and has seen continual usage and development ever since. NetLab's physical implementation, which can be seen in the photograph of Fig. 4, is located at the UniSA campus in Mawson Lakes, South Australia.

To provide an example of the potential applications of self-testing systems, NetLab will be considered as a candidate for self-testing development. NetLab does not currently feature a self-testing system, but it has the potential to utilise one. By considering the

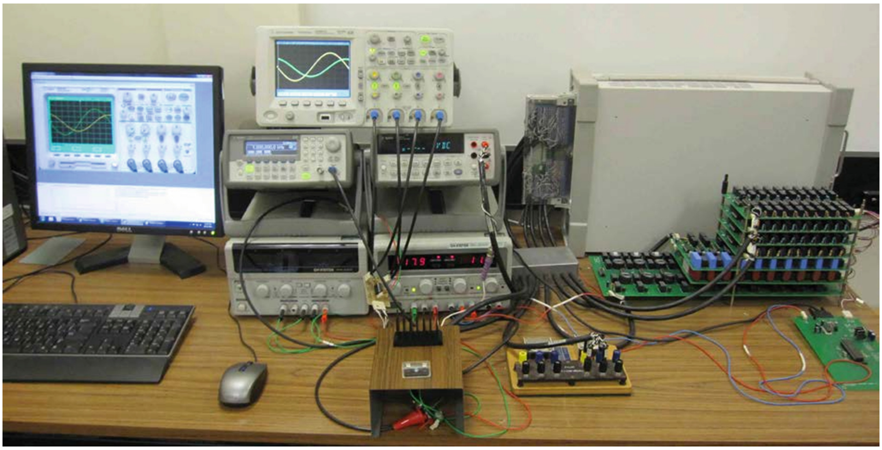

**Fig. 4.** Physical system of the NetLab remote laboratory [5]

potential application of self-testing systems to NetLab it may be possible to better understand their benefits.

### 4.1 Server

NetLab makes use of a dedicated server to support communication between its physical measurement equipment and its web interface [5]. The web interface for NetLab supports remote access over the internet from the web addresses http://netlab.unisa.edu.au/ and http://netlab2.unisa.edu.au/. The web interface also supports session bookings to use NetLab as well as chat communications between multiple users.

### 4.2 Measurement Equipment and Electronic Components

NetLab's measurement equipment includes a digital oscilloscope, digital multimeter, and function generator [5]. This equipment is used to measure various electronic components such as resistors, capacitors, inductors, transformers, and even circuits made from combinations of them. NetLab also includes a camera with dedicated web server that facilitates the remote viewing of its physical system in real-time.

### 4.3 Relay Matrix

Enactment of circuit connections and configurations is achieved through the combination of a relay matrix-switching unit and its specialised software [5]. By taking the role of intermediary, this relay setup allows the NetLab server to communicate back-and-forth with the physical components and test equipment.

### 4.4 Graphical User Interface (GUI) Software

In terms of software implementation, the NetLab GUI is coded in Java and thus requires the use of the Java Runtime Environment (JRE) in order to run [5]. The NetLab GUI is based on photographical depictions of real test equipment such as the oscilloscope, function generator, and multimeter. This has the twofold effect of making the controls intuitive to use and giving them the appearance and consequent familiarity of their real-life equivalents. The GUI provides an abstraction through which the end user can send instructions across the NetLab server and to the relay matrix where those instructions are acted out as physical reconfigurations to the NetLab system's hardware components. The GUI will also abstract the many individual resistors, capacitors, and inductors of the system into several variable resistors, capacitors, and inductors. For example, the GUI will present the end user with an interface for a variable capacitor whose value can be altered by adjusting a series of knobs. However, behind the scenes the relay matrix acts to connect various static capacitors together (in parallel) to summate to the end user's set value.

## 5 Application of Self-testing to NetLab

The methods of self-testing best suited for a system will depend on the overall objective of the system. In the case of NetLab, the objective being considered is the maximization of system's uptime. In order to achieve that the system must address and mitigate errors autonomously as they happen. This indicates that the self-testing system to be implemented should include a healing component. Thus, the system's self-test process flowchart matches with that of Fig. 1.

**Table 3.** Potential errors in NetLab

| Error source | Potential error and healing method |
|---|---|
| Server | *Error*: The server is physically functional, however it is no longer processing communications from the web interface to the measurement equipment |
| | *Rollback Healing*: Reset the server and monitor if it then begins to work. If still not working, then attempt rollback to a previous good configuration |
| Relay matrix | *Error*: Some of the relays are stuck open and thus prevent certain circuit combinations from being made |
| | *Reduction Healing*: Disable usage of the stuck relays, so as not to potentially damage them further. Continue operating with the remaining working relays at a reduced level of functionality |
| Electronic components | *Error*: Component fails and produces incorrect characteristics |
| | *Redundancy Healing*: Redirect usage of the failed component to an identical, spare component |
| GUI software | *Error*: A group of users have been using the chat communications non-stop for several hours. The chat (message) window has experienced a message cache overflow and will not process anymore chat messages |
| | *Repair Healing*: Incorporate a script of code into the GUI software that will detect the message cache overflow and clear it to allow for new messages to be processed |

For this case, the method of application will start with the identification of the main errors that the system is liable to encounter. These identified errors can also double as the detection requirements for the self-test system, since these errors are what it must detect. Next, suitable healing methods are developed to address the identified errors.

Based on the discussed NetLab architectures, a list of some potential error sources and methods of addressing them were tabulated into Table 3.

## 6 Conclusions

Having considered self-testing systems and their applications it is fair to say that they play an important role in the improvement of system maintenance and stability. Self-testing systems have the capacity to perform autonomous system maintenance and reduce the need for human intervention in the face of system errors. From the investigation of systems with self-testing functionality it was seen that even with differing methods, implementation, or features they all still benefit from the added capabilities. Additionally, having considered NetLab as a candidate for the theoretical integration of self-testing system functionality, it was found to benefit from such addition. This suggests that similar remote laboratory systems will also benefit from the integration of self-testing functionalities.

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## References

1. Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., Peire, J.: New technology trends in education: seven years of forecasts and convergence. Comput. Educ. **57**, 1893–1906 (2011)
2. Garcia-Zubia, J., Lopez-de-Ipiña, D., Orduña, P., Hernandez, U., Trueba, I.: Questions and answers for designing useful WebLabs. Int. J. Online Eng. (iJOE) **2**(3), 1–6 (2006)
3. Frei, R., McWilliam, R., Derrick, B., Purvis, A., Tiwari, A., Di Marzo Serugendo, G.: Self-healing and self-repairing technologies. Int. J. Adv. Manufact. Technol. **69**, 1033–1061 (2013)
4. Venishetti, S.K., Akoglu, A., Kalra, R.: Hierarchical built-in self-testing and FPGA based healing methodology for System-on-a-Chip. In: Second NASA/ESA Conference on Adaptive Hardware and Systems (AHS 2007), Edinburgh, pp. 717–724 (2007)
5. Teng, M., Nedic, Z., Nafalski, A.: Students' perception of remote laboratories—case study: NetLab. In: 2016 IEEE Global Engineering Education Conference (EDUCON), pp. 568–575 (2016)

# Design and Implementation of a Low-Cost and Modular Remote Lab Framework: Application to Electronic Sensors

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**Abstract.** In this paper, we propose a low-cost and modular remote lab framework, responding to the educational needs of technical disciplines and more particularly in electronics. It consists of two main parts: hardware and software. The hardware part is simple in its design, locally made, modular, scalable and can be easily integrated in with existing lab equipments. It is composed of a communication module and a configurable interface, linking this module to the experimental equipments. The interface is composed of a set of electronic boards each providing a specific function. The number and type of boards can be configured according to the educational needs.

The software part is a website, designed to be easily integrated into an e-learning platform. It is on a web server, linked directly or indirectly to the lab equipments and interacts with him through a software application. The student accesses through his browser, after authentication, to the website of the remote lab. He can control the hardware and get the measurement values sent by the server. The teacher has a special space to design and configure the lab.

The development of this framework is based on free software solutions and local developed hardware, thus avoiding the acquisition of costly digital equipment and expensive software licenses, consequently the development cost is reduced.

**Keywords:** e-Learning · Modularity · Remote lab

## 1 Introduction

Distance education has existed from many decades [1]. Based on self-study, the learner in this form of education often received his pedagogical material (documents, equipment for some disciplines) by post. His assessment was often done in a face-to-face manner, where possible. With the emergence and then the generalization of the use of the Internet [2], a new form of distance education has appeared: remote education or e-Learning [3]. The technical disciplines, where the learner has to practice real manipulations, quickly


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lead the imagination of the specialists towards the creation of adapted devices for this new kind of educational lab [4].

## 2 Remote Lab Overview

Experimental labs can be classified, according to the way user's access and the nature of the equipment, in four modes [5]:

- Face-to-face mode: lab takes place with the physical attendance of the user in the same place as the actual physical equipment.
- Virtual mode: the user manipulates virtual equipment locally.
- Remote virtual mode: the user manipulates virtual equipment remotely.
- Remote real mode: the user manipulates real equipment remotely.

The last mode is the subject of this paper. It refers to the hardware and software package that allows the user to do remotely experimental labs. It offers many advantages:

- Doing the lab several times in order to reach a better assimilation of the theoretical concepts.
- Saving of time and effort: no physical displacement.
- Serving a large number of students which is impossible in face-to-face mode.
- Sharing of resources and lab equipments between laboratories and establishments, which considerably reduce the cost of acquiring equipments.
- Working even on weekends and holidays.
- Reducing the idle time by better use of equipments lab.

There are a multitude of remote lab devices that differ by the architecture or by the used technologies and tools. The majority of these systems are dedicated to predefined applications by the designers [6]. They often require digital control and acquisition equipment, acting as an interface between the computer and the equipments lab, which remains relatively expensive. In addition to the hardware, a software infrastructure is essential for its operation. Designers often make use of specialized proprietary software that will increase the cost of the entire device. This has lead us to design a simple and inexpensive remote lab system that can be easily made, and then can be available to educational institutions, especially those with limited financial resources, in order to integrate this new technology into teaching practices.

## 3 Proposed Approach

Like any remote lab device, ours is designed with a software and hardware parts. It must meet a set of criteria that we have defined in order to reach the desired purpose.

The hardware part must be simple in design, simple to use, made with low cost, modular, scalable and can be easily integrated in existing equipments lab.

The software part must be developed with free tools to minimize cost, simple and easy user interface, multi-operating systems (Windows, Linux and others) and scalable.

### 3.1 Specifications

The technical translation of these criteria conducts us to propose the following specifications:

- Client-server architecture.
- The server is linked directly or indirectly to the equipments lab.
- The client accesses through his web browser to a web page that represents the remote lab portal. It is made by authentication system based on username and password. This page must be stored on the server.
- It interacts indirectly with the equipments through a software program.
- The user can control the equipment lab through this web interface and get data sent by the server. Access to the equipment lab is exclusive.

### 3.2 Remote Lab Framework Design

In this section, we present the design of our remote lab framework. Let's start with the intranet approach that leads to a solution to be used on the institution intranet. Access with an extern client computer is made through the main server of the institution which represents the internal resources access portal.

Figure 1 illustrates the remote lab framework diagram. It consists of two parts: hardware and software.

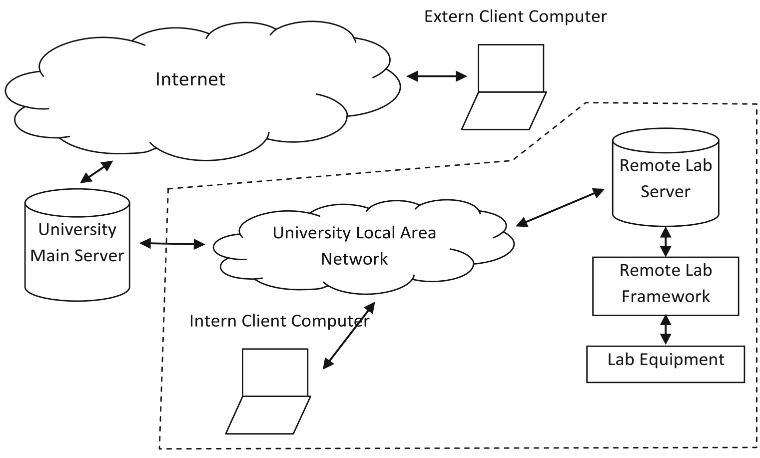


**Fig. 1.** Remote lab framework diagram.

**Hardware design**

The proposed hardware is based essentially on a locally realizable solution. It consists of two main parts.

*Communication Module*
This is the physical gateway between the computer and the equipments lab (see Fig. 2). Its main task is the routing of data and commands in both directions (bidirectional). These data can be digital or analog. This module can be realized in different forms, we opted for a circuit based on a low cost microcontroller whose characteristics exceed even our current needs. Through its input and outputs ports, we provide bidirectional communication between the computer and the equipments lab, via a power and isolation interface.

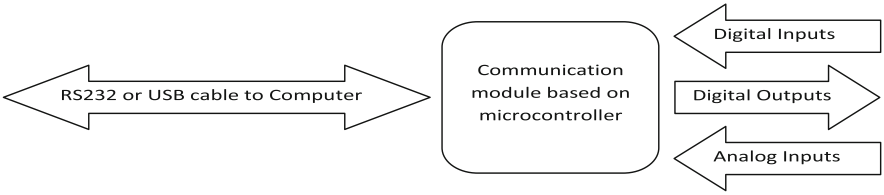


**Fig. 2.** Communication module interactions.

*Power and isolation interface*
This interface is a hardware collection composed of electronic boards each having a well-defined task. The number and the type of boards to be used in a lab depend on the hardware configuration required by this lab and can vary from one lab to another. The interface ensures a separation between the control part, represented by the communication module, and the operative part which is the equipment lab (see Fig. 3). This separation is made by the use of the optoelectronic components thus providing galvanic isolation and enhanced by current amplifiers and power stages controlling the elements present in the equipments lab which often require voltages and currents that the control part can not provide.

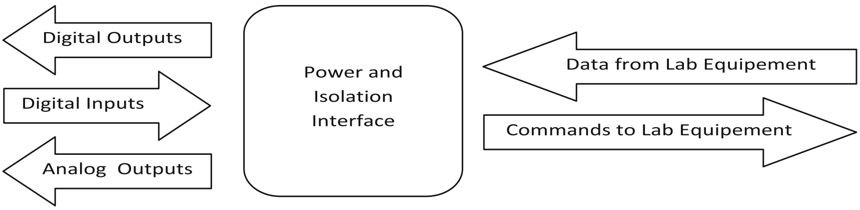


**Fig. 3.** Power and isolation interface interactions

**Software design**
The proposed diagram of the software part is shown in Fig. 4. The student accesses through his web browser to a page that presents the remote lab portal. Access to the lab page is done by authentication (username and password). The authentication page is stored on the server. The correct authentication makes it possible to direct the student towards the page of the chosen lab which contains the different steps to do the lab.

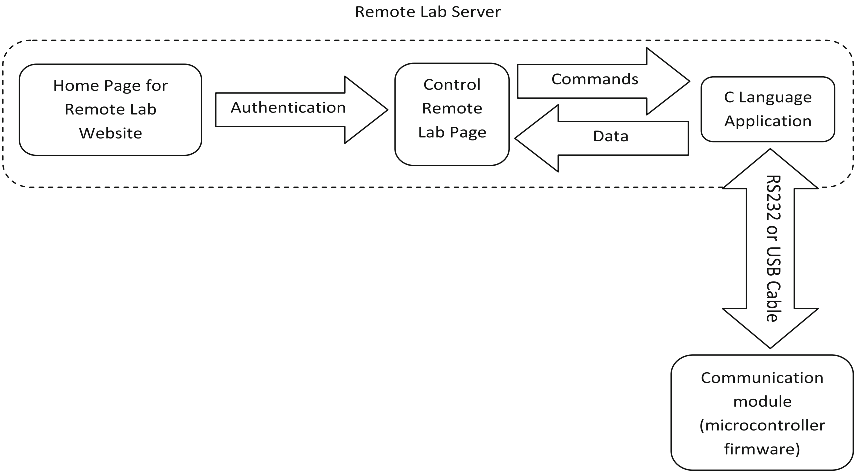


**Fig. 4.** Software part diagram.

Access to the lab page is made after verification of the following conditions:

- The lab page must not be opened by another student.
- A student can not access to two pages (labs) simultaneously.
- The lab page is followed by a manipulation page that allows hypertext links to send commands and receive data through the communication module.

The commands are sent by the server as a string. It interacts indirectly, via a program developed in C language, with the communication module. The module converts this information into commands enabling it to control the equipment lab.

## 4 Results

The design of the remote lab framework previously exposed allowed us to create a website representing the user interface on the one hand, and on the other hand a hardware collection composed of electronic boards each having a well-defined task.

We present a practical example illustrating the principle of operation of the proposed framework. We have configured the system for the study of a light sensor such as a Light Dependant Resistor (LDR). This study consists of taking measurements of voltages in order to characterize the LDR in an illuminated and dark environment. It requires controlling a lamp, the measurement of three analog voltages, controlling of a power supply source (see Fig. 5). The power and isolation interface hardware configuration is composed of three analog input boards and two output based relay boards (see Fig. 6).

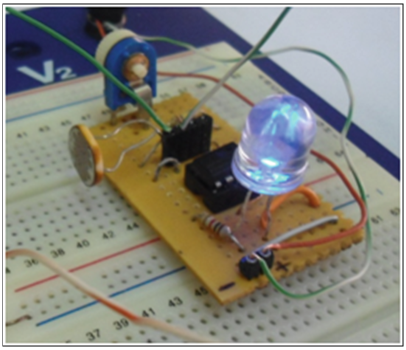

**Fig. 5.** LDR board.

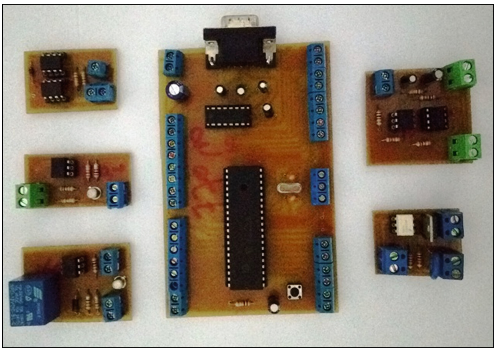

**Fig. 6.** Electronic boards.

The manipulation is described as follow:

- Student accesses through his web browser to a web page that represents the remote lab portal (see Fig. 7). He can choose one lab from the labs list (see Fig. 8).


**Fig. 7.** Remote lab portal.

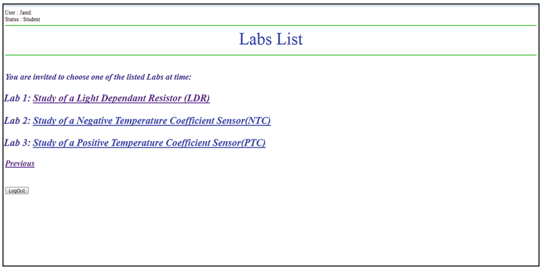


**Fig. 8.** Labs list.

- On the lab displayed webpage (see Fig. 9), he can read a lab description then by simple click on the schematic image, he will be redirected to the lab manipulation webpage (see Fig. 10).

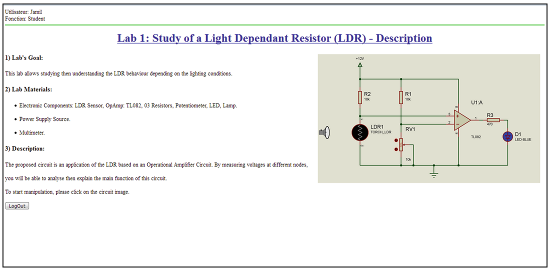


**Fig. 9.** LDR lab webpage


**Fig. 10.** LDR lab manipulation

- He must click on the hypertext link to execute chosen command on the lab webpage.
- Remote lab server receives this command in text form then sends it to the communication module.
- It translates this command to digital (or logical) level and loads the corresponding output pin by this value.

- The isolation and power interface receives this logic state and translates it to an electrical voltage that can switch relay, for the case of relay control.

Suppose now that we want to measure one of point voltages present on the experimental board:

- The student computer sends the measure voltage command to the remote lab server which transmits it to the communication module.
- The module starts an analog to digital conversion of the voltage present on one of its analog inputs. This input is connected through an analog input board to the voltage node. The student can upload then store the measured voltage value on its computer.

## 5 Conclusion

The proposed solution is very interesting because of its ease of implementation, its low cost and its modularity, which will allow enriching it and adapting it for other types of experimental lab even outside electronics' labs.

## References

1. Orivel, F., Orivel, E.: Analyse économique de l'e-Learning: quelques pistes pour le futur, keynote lecture. In: XXIIe Conférence de la CESE Grenade, 3–6 juillet (2006)
2. Rajani, M.K., Chandio, M.S.: Use of internet and its effects on our society. In: National Conference on Emerging Technologies 2004, Session VIII Paper No. 2, pp. 157–161 (2004)
3. Bohus, C., Aktan, B., Shor, M.H., Crowl, L.A.: Running Control Engineering Experiments Over the Internet. Oregon State University, Technical Report 95-60-7, August 1995
4. Gomes, L., Garcia-Zubia, J.: Advances on remote laboratories and e-learning experiences. Publicaciones Universidad de Deusto (2007)
5. Nedic, Z., Machotka, J., Nafalski, A.: Remote laboratories versus virtual and real laboratories. In: 33rd ASEE/IEEE Frontiers in Education Conference T3E-1, 5–8 November 2003, Boulder, CO (2003)
6. Matarrita, C.A., Concari, S.B.: Remote laboratories used in physics teaching: a state of the art. In: 13th International Conference on Remote Engineering and Virtual Instrumentation (REV) (2016)

# Experiences with the Use of Pocket Labs in Engineering Education

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**Abstract.** This paper describes the two-year experience at CUAS regarding the use of Pocket Labs, which are small, portable pieces of hardware, combined with free or affordable software, thus enabling students to be free in place and time for carrying out laboratory exercises. Results from evaluation questionnaires show that Pocket Labs are widely accepted by students, especially time flexibility is an important issue for evening students.

**Keywords:** Pocket Labs · NI myDAQ · Raspberry Pi
Electrical engineering · Image processing

## 1 Introduction

Pocket Labs, which are herewith defined as small, portable pieces of hardware, combined with free or affordable software, thus enabling students to be free in place and time for carrying out laboratory exercises, are a quite new movement in schools and universities. Figure 1 shows a summary of laboratory concepts, both classical and recently developed.

- Classic labs take place at the campus as usual; students do exercises in groups at a predefined time, with different success levels.
- Remote labs are located at University locations as well, with the difference, that students can remotely log in from another location and control actually existing hardware.
- Pocket Labs, finally, are again uniting the locations of students and labs; however, this location can now be anywhere. Moreover, they enable students to be more time flexible to do their exercises.

## 2 Pocket Labs at CUAS

At CUAS, some attempts were made to establish the use of Pocket Labs during the last three years; further options are under development [1]. Currently, two Pocket Lab systems are in use.


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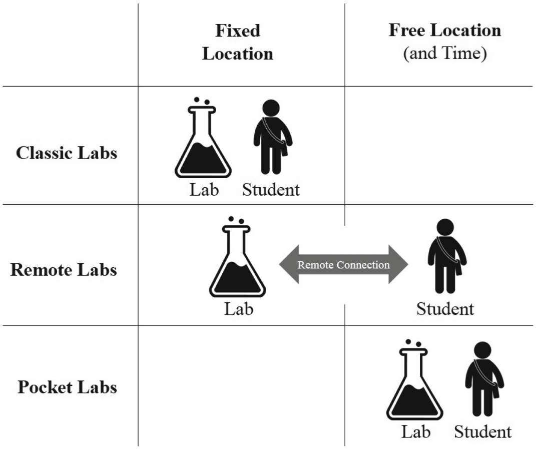


**Fig. 1.** Laboratory infrastructure concepts and methods [2]

### 2.1 NI MyDAQ for Electrical Engineering and IT Exercises

The myDAQ devive from National Instruments is an affordable, lightweight handheld device for performing measurements with a virtual oscilloscope, multimeter, function generator, and other useful instruments. Own instruments and applications can be developed using LabVIEW™. The device contains also an expansion plug for the connection of sensors and actuators, or a breadboard for custom circuits (Fig. 2).

At CUAS, the myDAQ is used for instance for programming exercises in IT education [3]. For this purpose, a so-called mini system with switches, LEDs, and other control and indication elements was created, so that students can perform hardware-related programming. Another application is the measurement and simulation of electric and electronic circuits in electrical engineering exercises [4,5]. Here, the circuit built on the breadboard can be measured as well as simulated with the same virtual instruments.

### 2.2 Raspberry Pi for Image Processing and IoT Applications

The advantages for using mini computers such as the Raspberry Pi in engineering education are obvious. As an example, the use of the Raspberry Pi in image processing lectures is shown. Together with the optional available camera and the free image processing library openCV, the Raspberry Pi forms a cheap but reasonable powerful image processing system, that can be handed to each student. Based on the portability, students are enabled to carry the entire system with them and perform exercises and measurements at the University, at home, or actually at any place they like (Fig. 3).

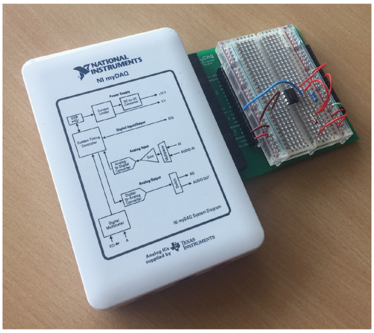


**Fig. 2.** National instruments' myDAQ with breadboard circuit

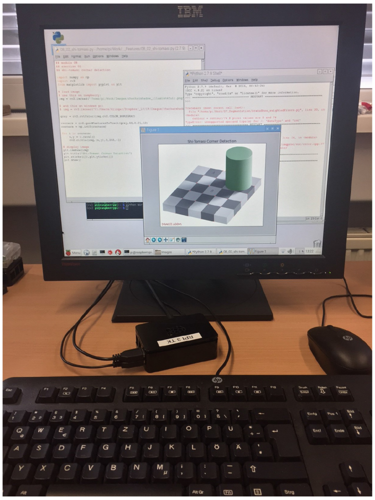

**Fig. 3.** Raspberry Pi performing image processing exercises

## 3 Further Considerations for the Use of Pocket Labs

It is clear, that Pocket Labs will not (and maybe never) substitute any of the other mentioned laboratory concepts, as they can only be used for a limited area of exercises, especially for those which are using standard and cheap components. Any lab equipment with significant costs or safety requirements will have to remain at the University campus for obvious reasons.

Consequently, an ideal solution would combine all of the concepts, if possible. Guidelines for concept combinations can be for instance [2]:

– Pocket Labs are ideal for measuring standard (thus cheap) components. Measuring unknown components (aka "black boxes") is not practicable, as they would have to be provided to each student, leading to high effort. Therefore, such measurements are better done using remote or classic labs.
– Pocket Labs can be used for the preparation of more complex exercises. For instance, the *i*-*v*-characteristics of a transistor can be measured in advance with a Pocket Lab; in a subsequent classic lab the data can be used to build a two-stage differential amplifier.
– An image processing Pocket Lab can be used to learn the principles of image properties such as edges, objects, and others. This knowledge can later be used to program an auto-focus algorithm at the University, using either remote or classic lab infrastructure.

## 4 Student Perception and Impact

Students at CUAS are provided an additional questionnaire appended to feedback forms that are regularly used to get student feedback. This questionnaire consists of the following four question (marked Q1 to Q4):

- Q1: *"Pocket Labs supported my understanding of the content of this lecture."*
- Q2: *"The flexible time management when using Pocket Labs was ..."*
- Q3: *"The use of Pocket Labs in this course makes the content more descriptive."*
- Q4: *"Overall, I consider the use of Pocket Labs in this course ..."*

The answer possibilities were realized with specific matching words, ranging from positive to negative. Here, the answers will be displayed using the symbols "++", "+", "−", "−−", and "n.a." for "not applicable," respectively [4]. From a total number of $n \approx 80$ each, Fig. 4 shows the results for regular (daytime) students, Fig. 5 the results for evening (or part-time) students.

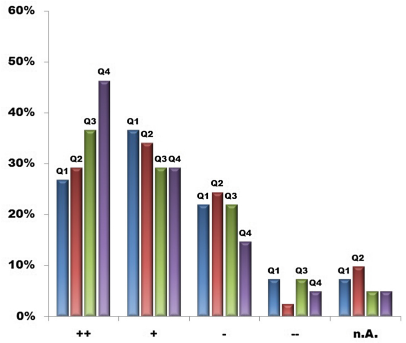


**Fig. 4.** Detailed feedback from regular students [4]

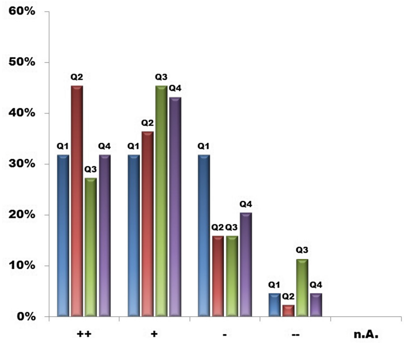


**Fig. 5.** Detailed feedback from evening students [4]

It can be seen, that Pocket Labs are generally accepted by regular as well as by evening students, although some scepticism is still there, most likely from students who need some personal guidance for practical laboratory exercises. Here is still some work to be done regarding tutoring or other didactic considerations.

The most significant difference between the feedback results of the two student groups can be seen in Q2, which deals with the flexible time management for the laboratory exercises. Here, evening students see this aspect as the biggest advantage of Pocket Labs, which is obvious due to the fact that they have to do their studies in parallel to their regular job. In that case, everything that makes time management easier is naturally welcome.

Finally, Fig. 6 shows weighted feedback results for the four questions. To get these results, the number of answers in each category was multiplied with

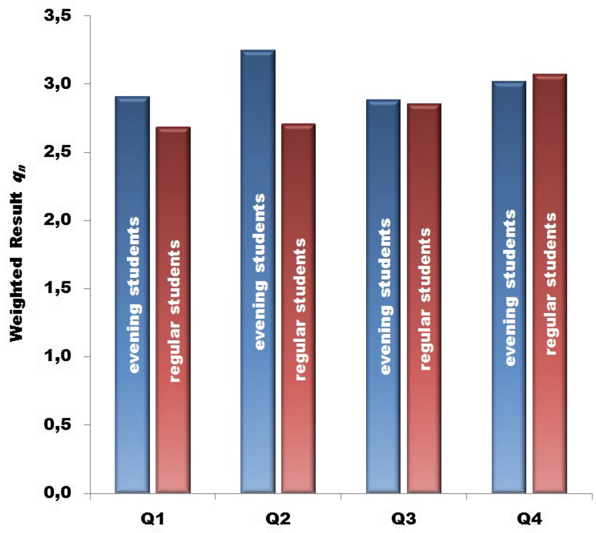


**Fig. 6.** Weighted feedback results [4]

a weight, higher for positive and lower for negative answers. Again, it can be seen from Fig. 6, that Q2, dealing with the flexible time management, is a more important issue for evening students as for regular students.

## 5 Conclusion and Outlook

The importance of Pocket Labs will increase in the future. Although the use of Pocket Labs gives a number of advantages to students and teaching staff, some additional actions should be discussed in order to gain maximum effort. For instance, such actions could be:

- Similar to "flipped classroom" teaching methods, Pocket Labs enable a "flipped lab" model, both of which may be combined in the future, thus bringing further advantages.
- Additional mentoring of students regarding the use of Pocket Labs will be absolutely necessary, especially for students in lower semesters.
- Further technologies as well as further applications have to be developed. Technologies may include different hard- and software, which may be even more affordable and easier to use for students; applications have to be found in curriculum topics.

## References


1. Pester, A., Klinger, T.: "Analog computing with Pocket Labs," Experiment@ International Conference (exp.at 2017), Faro (2017, submitted)
2. Klinger, T., et al.: Parallel use of remote labs and Pocket Labs. In: 14th International Conference on Remote Engineering and Virtual Instrumentation (REV2017), New York (2017)
3. Madritsch, C., et al.: Using Pocket Labs in master degree programs. In: 19th International Conference on Interactice Collaborative Learning (ICL 2016), Belfast, UK (2016)
4. Klinger, T., Madritsch, C.: Collaborative learning using Pocket Labs. In: International Conference on Interactive Mobile Communication, Technologies and Learning (IMCL 2015), Thessaloniki, Greece (2015)
5. Klinger, T., Madritsch, C.: Use of virtual and Pocket Labs in education. In: 13th International Conference on Remote Engineering and Virtual Instrumentation (REV 2016), Madrid, Spain (2016)

# Work in Progress: Pocket Labs in IoT Education

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**Abstract.** This work in progress describes the ongoing initiative at CUAS to use Internet of Things (IoT) technologies for educational purposes. First, it describes the relevance of Internet of Things technologies in education, next it focuses on different hardware platforms used by CUAS. The main part describes the implementation of one specific example developed by students, the MIA-project. Finally, it gives an outlook on how future student projects will benefit from the lessons learned.

**Keywords:** Internet of Things (IoT) · Bachelor degree program
Raspberry Pi · Arduino · Teensy · Blend Micro
Project-based learning · Pocket Labs

## 1 Introduction

Internet of Things (IoT) technologies tend to be one possible future of engineering in general. In the last 2–3 years in Higher Education the trend to a Maker University is one of the mainstream trends. For engineering study programmes, which traditionally had both, a theoretical and a lab part, this means at first instance the close (thematically and from a timeline point of view) connection of the experimental and theoretical part of teaching.

IoT technologies incorporate many different aspects of technical systems. They usually consist of a microprocessor/microcontroller which can be used stand alone or with an operating system, e.g. Linux. The application software can be programmed using the traditional C/C++ approach or by applying emerging programming languages like Python and Processing. IoT systems are equipped with interfaces to the outside world, both analogue and digital. Sensors, attached to these interfaces can measure a wide range of physical entities with astonishing precision and sampling rate. Last, but not least, IoT systems are equipped with communication means to interact with other IoT devices. Bluetooth, Zigbee, WiFi, and LoRaWAN are some of the possible choices.

During the last years, CUAS has successfully introduced various kinds of IoT systems and technologies into a growing group of bachelor degree courses (e.g. Real-Time Systems, Bus systems and Protocols, Algorithms and Datastructures). This work in progress description provides an overview about different kinds of IoT systems currently used at CUAS. It also explains one specific IoT student-project in detail.


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## 2 IoT at CUAS

At CUAS, we are using different IoT architectures and systems. Since different applications demand different levels of complexity, speed, composability, and interoperability, the one fits all solution cannot and will not be applied.

Arduino is one major IoT device used by CUAS. Due to its ease of use and high flexibility, it is the ideal choice for beginners as well as for experienced students. The integrated development environment (IDE) with its built-in Processing programming language and the high number of extension boards (shields) with corresponding software libraries provide a limitless playground for various kinds of projects.

We use Arduino as a base platform which means that depending upon the current requirements of our applications, students need to choose a clone-version. Two clones we are using are the Blend micro and the Teensy board.

The Blend Micro board (see Fig. 1) is at its heart an Arduino blended with a Bluetooth Low Energy (BLE) interface into a single board. It is targeted for makers to develop low power Internet-Of-Things (IoT) projects quickly and easily. The micro-controller unit (MCU) is Atmel ATmega32U4 and the BLE chip is a Nordic nRF8001. Blend Micro runs as BLE peripheral role only, it allows BLE central role devices to establish connections with it [1].

The Teensy 3.2 USB development board (see Fig. 2) is a complete USB-based microcontroller development system in a very small footprint capable of implementing many different types of projects. The Teensy is a breadboard-friendly development board. Each Teensy 3.2 comes pre-flashed with a bootloader and can be configured directly using USB. It can be programmed in C or by using Arduino sketches for Teensy. The processor on the Teensy also has full access to the USB and can emulate any kind of USB device [2].

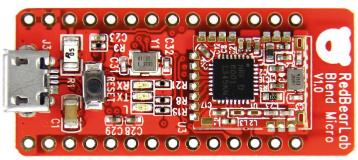


**Fig. 1.** Blend Micro board.

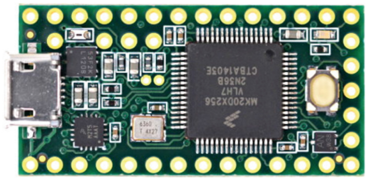

**Fig. 2.** Teensy 3.2 board.

The Raspberry Pi 3 Model B (see Fig. 3) has a 1.2 GHz 64-bit quad-core ARMv8 CPU, 802.11n Wireless LAN, Bluetooth 4.1, Bluetooth Low Energy (BLE). It is used in combination with extension-boards, breadboards, cameras, sensor/actor kits, etc. The Raspberry Pi is setup with the appropriate OS (Raspbian, Windows 10 IoT, Ubuntu). Programming takes place using Python, C or C++ [3].

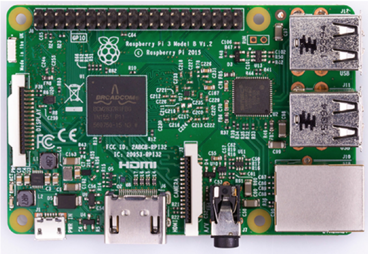

Fig. 3. Raspberry Pi 3.

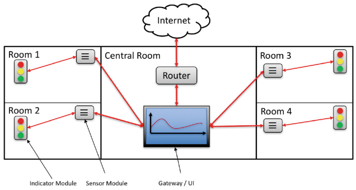


Fig. 4. MIA Overview.

## 3 Managed Indoor Air (MIA) Student Project

### 3.1 General Overview

The goal of the MIA student project was to develop an air measurement system using IoT technologies. The three main aspects of this project were: the choice and configuration of the hardware, software development for different target platforms, and the configuration of the appropriate communication interfaces.

The whole application was split into three IoT modules (see Fig. 4):

- the Sensor Module, capable of measuring the CO2 concentration of the air, the air temperature and the humidity,
- the Indicator Module, providing a simple and intuitive way to show humans when to open a window to ventilate, and
- the Gateway Module, which is used to graphically represent the acquired data from the sensor module and it also acts as the gateway into the internet and portal for a cloud-based storage system.

To interconnect the three different modules, a communication architecture was developed (see Fig. 5). The final choice was to use BLE to connect the Sensor module to both, the Indicator module and the Gateway module and to use WiFi to connect the Gateway module via a router to the internet.

### 3.2 Sensor Module

The purpose of the Sensor module (see Fig. 6) is to measure the CO2 concentration of the air, the air temperature and the humidity and to transmit this data using BLE to the Gateway Module.

The Sensor module consists of the following components:

- Teensy 3.2 (Arduino compatible IoT device),
- Adafruit BME280 (temperature and humidity sensor),
- Telaire T6615 (CO2 Sensor), and
- BLE2 Click (BLE Module).

The CO2 Sensor and the BLE Module are connected to the Teensy using UART, the BME280 uses I2C as its interconnect (see Fig. 7).

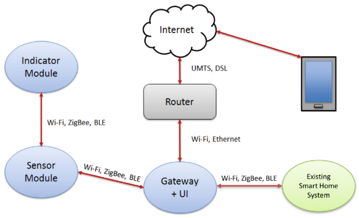


**Fig. 5.** MIA Communications Overview.

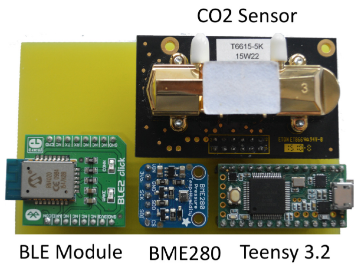


**Fig. 6.** Sensor module.

### 3.3 Indicator Module

The purpose of the Indicator module (see Fig. 8) is to provide a simple and intuitive way to show humans when to open a window to ventilate by using a RGB LED. If the LED is turned off, the air quality is good. If the LED turns on to yellow, the air quality is medium, and if the air quality is bad, the LED turns to red. After the air quality has reached a good level again, the LED turns off.

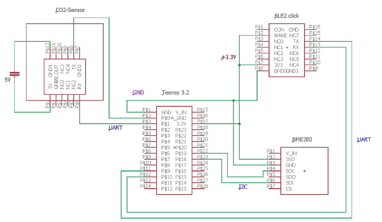

**Fig. 7.** Sensor module internal interconnects.

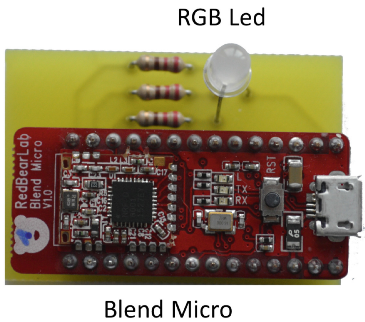


**Fig. 8.** Indicator module.

The Indicator module consists of the following components:

- Blend Micro Board,
- RGB Led, and
- BLE module (integrated).

### 3.4 Gateway Module

The purpose of the Gateway module (see Fig. 9) is to graphically represent the acquired data from the sensor module and to act as the gateway into the internet and portal for a cloud-based storage system.

The Gateway module consists of the following hardware components:

- Raspberry Pi 3,
- Raspberry Pi 7" LCD Touchscreen,
- BLE Module (integrated), and
- WiFi 802.11n (integrated).

The Raspberry Pi 3 is using Raspbian a Debian Linux clone as operating system. The following software components are also installed on this IoT-device (see Fig. 10):

- Apache 2.4.10 Webserver,
- SQLite 3,
- Python 2.7,
- PHP/HTML,
- Google Charts API, and
- Chromium.

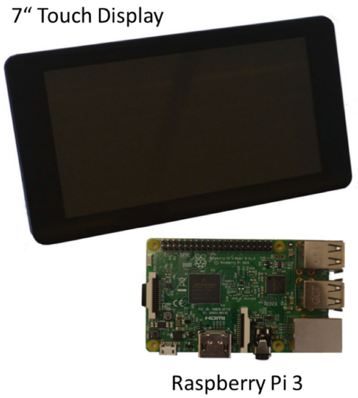


**Fig. 9.** Gateway module.

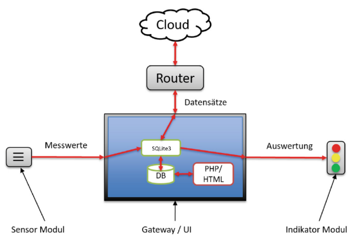


**Fig. 10.** Software components.

SQLite is managing the database (DB), Apache Webserver acts as the external interface to the DB and PHP/HTML are the transport protocols used. The Google Charts API is used to draw diagrams and Python is used as the programming language.

### 3.5 Overall Results

The IoT student project MIA was very successful. Three students have been working over a period of seven months and completed the project not just in time but also three weeks earlier. The budget was not overspent and two independent MIA systems have been build. They are being used at CUAS and they certainly are references for future projects in this field.

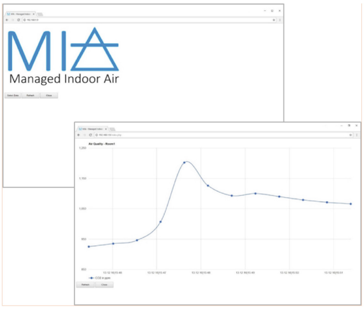


**Fig. 11.** GUI Measurement results.

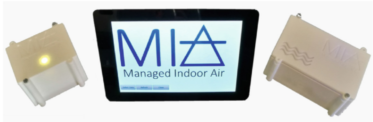


**Fig. 12.** Final MIA system.

In Fig. 11, the graphical representation of the measurement results on the Gateway module can be seen. The same representation can be accessed via the Internet using a browser or a Smartphone.

The project group also designed and constructed housings for the individual modules, which can be seen in Fig. 12. The in-house 3D-printer of CUAS has been used.

## 4 Outlook

Due to the large and obvious relevance of IoT technologies, students are very much interested in similar and future IoT projects. Not all projects require a complete hardware and software design from scratch the challenge in the future will be to identify candidates for the IoT approach and the others intended for custom embedded systems design.

As the developed modules can be used for mobile measurements as well as for laboratory exercises, they satisfy the definition of Pocket Labs [4], being portable electronic devices for mobile measurements.

## References

1. http://redbearlab.com/blendmicro/
2. https://www.pjrc.com/teensy/
3. https://www.raspberrypi.org/
4. Madritsch, C., Klinger, T., Pester, A., Schwab, W.: Work In Progress: Using Pocket Labs In Master Degree Programs

# Talking About Teaching

# Entrepreneurship in the Dual Engineering Training Curricula

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**Abstract.** The study presents the new experiences of the dual training model in engineering education as a best practice example. This new model has been introduced recently in the Hungarian higher education and has become a focus of interest. The dual education students study in the institutional academic period together with the normal full-time students at their higher education institute, and parallel to their academic education they participate in the practical training. It gives the students an opportunity to join a specific training program at an enterprise. Being involved in specific "operational" practical tasks and project-oriented work enhances independent work, learning soft skills and experiencing the culture of work. Among all these knowledge areas entrepreneurship studies have been added to both the academic and the practical curriculum. Our aim is to present this new type of engineering education compared to the traditional curriculum, focusing on entrepreneurship studies. We highlight the contents of the academic curriculum and its practical contents at different enterprises. The present paper examines the difference in terms of the entrepreneurial knowledge and learning process between the dual and traditional students after participating for a year in these different educational models.

**Keywords:** Dual study · Learning by doing · Soft skills · Entrepreneurship Engineering curriculum

## 1 Introduction

Hungarian Universities introduced the dual study model based on German experiences in 2015. The Hungarian Higher Education Act was amended in 2014 and it defined the role and place of this new form of training in higher education.

The dual education students perform during the study period, the academic period, for 14 weeks per semester, together with the normal full-time students in their higher education institute. After this period they participate in the practical training, the corporate period lasting for 8 plus 16 weeks in the academic year at an enterprise, which has a cooperation contract with the university (Fig. 1). During the corporate period the student gains specific professional knowledge and practical working practice at the enterprise as trainees according to their contract [1].


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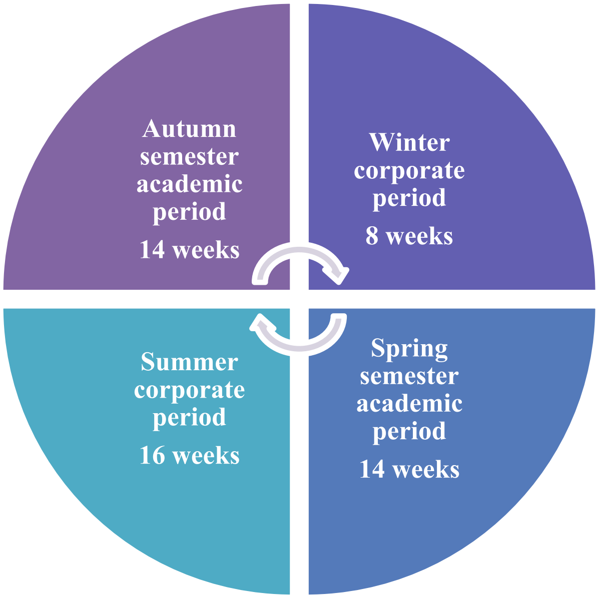


**Fig. 1.** Dual study model

Domestic and international experience highlight the effectiveness of dual training [2–4]. Dual training increases professional competences and the knowledge base obtained in the company environment, by integrating the established curriculum content, structure, a sufficient internship period and the practical experience gathered from professionally qualified companies [5]. This allows students to benefit from exiting higher education and enter the labor market as strong contenders eliminating the years of extra training and additional financial expenses.

The dual form of training can be beneficial for all three parties: the student, the company and the university. The students can gain practical knowledge during their studies, facilitating better job prospects after the training, and their income can ease financing their training as well. However, it is important to note that participation in this type of training requires a certain degree of maturity, high level of motivation, because the coordination of work and study is difficult. For companies, this form of training allows them fulfilling their need for well-trained labor, and the transfer of knowledge ensures professional recruitment [6]. Universities expect more motivated students, a regular lively cooperation with enterprises, and higher level of social awareness, recognition and increased interest.

An investigation of the International Company, IBM, in Germany, suggested that cooperative education graduates show rapid career advancements. An interesting aspect of this observation is the fact that, dual students at IBM, have higher salaries and hold higher positions over similar students from traditional universities [7].

According to Burns and Chopra [8] successful industry engagement provides students with different experiences in networking connections with professionals who can potentially provide employment references and future job positions for them, practical experience by observing and applying the methods and theories learned in classroom to real-world scenarios, allows students to gain experience in their prospective career path, and improves students' professional communication skills.

## 2 Dual Study Model, Learning by Doing in the Higher Education

The model of the situated learning is based on the traditions of the historical guild education. Apprenticeship is a way of learning for a newcomer, the strength of which is to introduce their members to the "learning in community" practice, which is a cornerstone of workplace training for professionals in the field of knowledge creation and professional development [9]. According to Lave and Wenger [10], learning is not just the transfer of abstract and decontextualized knowledge from one person to another, but a social process in which knowledge is jointly built. They think that such learning can be defined in a particular environment, embedded in a particular social and physical environment. Knowledge is nothing but a highly valued competence, and acquiring this knowledge depends on participating in a group whose members already have this competence and who are willing to allow the learner to gradually become more involved in their community (as in the Middle Ages it happened in guilds). With time-controlled observation and practice, where hidden knowledge is important, the students are moving from the periphery towards the center by increasing their participation in the community of practice. By doing so, learning is merged with work.

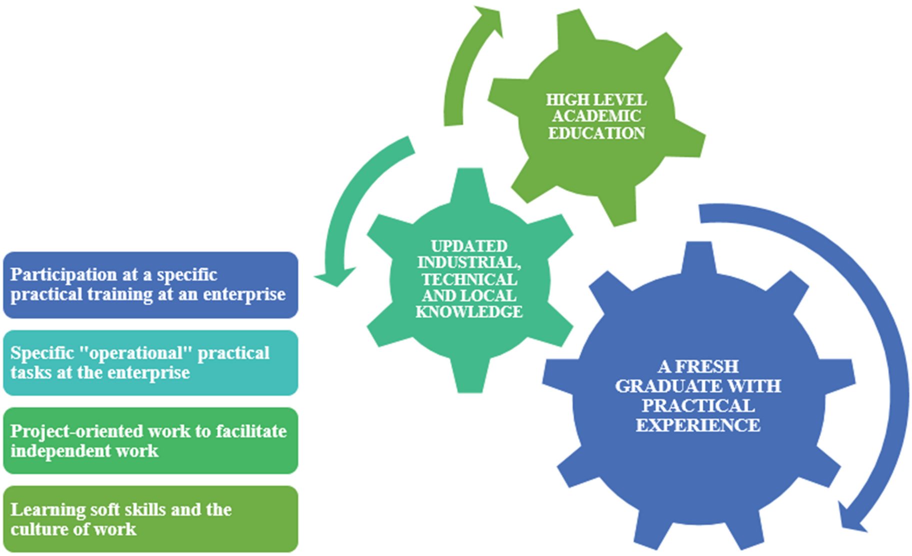


**Fig. 2.** The elements of dual training

It is commonly criticized that university engineering training is not able to train professionals who fully meet the industry's expectations being far from the world of industry. In the world of permanent changes today, due to the constantly changing economic and social environment, industry requires practitioners with experience-oriented training (Fig. 2). Due to its structure, the current traditional two-stage training does not offer sufficient opportunities for practical training. On reason of it is there are less university instructors with up-to-date industrial skills. Another reason is the insufficient acquisition of the so called soft skills (i.e. leadership skills, co-operation skills, corporate culture, etc.) in the higher education institutions [6].

These expectations justified the introduction of dual training in technical higher education. The strong theoretical knowledge acquired during the academic semester in dual training is immediately applied at the companies in the corporate period. In addition to the curriculum related to a particular discipline, students also acquire theoretical and practical knowledge of skills required at the company. The knowledge of the students participating in the training meets the needs of the companies they work at, so the societal return of the training is significantly faster. Dual training responds to the labor market expectations much faster than traditional engineering training.

## 3 The Entrepreneurship Curriculum in the Dual Study Model

As described earlier the dual students participate at the lectures during the academic period together with the traditional students. Between the academic periods there are the corporate periods, while the students learn and work at their companies. The students have an opportunity to deal with different topics in practice right after learning about it at the lectures at the university. The corporate curriculum contains different topics, which are transferred by different experts at the company (Table 1).

**Table 1.** Entrepreneurship: elements of academic and corporate curriculum (Obuda University Alba Regia Technical Faculty, mechanical engineering dual study program, semester 1–2.)

| Academic curriculum | Corporate curriculum |
|---|---|
| Business Economics I.–II.<br>1. Main features of the enterprise. Entrepreneurial forms. The organization of the company<br>2. Elements of value-creating production process. Production planning calculations<br>3. Market activity, marketing<br>4. Resources. Circulation of company resources. Property management. Rotating asset management. Workforce management<br>5. Economic studies. Production management and economy. Property and finance in the business | Corporate processes and products, understanding and producing corporate documents<br>1. Marketing process<br>2. Logistics process<br>3. Manufacturing preparation process<br>4. Manufacturing device assurance process<br>5. Manufacturing process<br>6. Human resources management<br>7. Management process<br>8. Quality management<br>9. Environmental management<br>10. Project design, project implementation<br>Informatics process |

The dual student has the opportunity to understand the interrelation among different enterprise subsystems, instead of seeing them as separate subjects at a course. It is possible to present them the system as a whole, the connection points among controlling, accounting, marketing, HR, procurement, logistics etc. During the lectures dual students are more active, they show more interest toward the different entrepreneurship knowledge areas. They share their experiences gathered in the business context and check the areas they learned about at the academic institution. There are more courses engineering students take part in during their studies in connection with entrepreneurship: Business Economics, Management, Quality Assurance, Energy Management and Environmental Protection, Legal Knowledge, Human Resource Management, Logistics etc. In our program we focus on the first year experience both at the academic and the corporate side. The reason is that the pilot project of the dual study model is in an introductory phase at present, we only have students in the first two years.

## 4 Research About the Entrepreneurship Knowledge Among Dual Students Compared to Students in the Traditional Model

In our empirical research we examined the special features of dual training compared to traditional training in teaching entrepreneurship knowledge.

Participants were 32 students majoring mechanical engineering and technical management, all first year students of the Obuda University. Their mean age was 20 years, SD 1.6. 59% (N = 19) were dual students, 41% (N = 13) were non-dual students. 59% (N = 19) were majoring mechanical engineering, 41% (N = 13) were majoring technical management. All students attended in the spring semester of 2017 Business Economics course, and they have just written their end-of-term test in the subject.

All participants completed a questionnaire first about the skills obtained at the university or in the entrepreneurial context in the topics of the entrepreneurship. After the survey, all students participated in one of the three focus groups, which could reveal more detailed information and deep insight in their views.

The questionnaire measured the prior knowledge of business topics of the Business Economics course and the prior business experience (knowledge acquired in a dual practice, knowledge gained from other work experience such as summer student work, secondary school practicum etc.). We measured the prior business experience in 5 topics (entrepreneurial forms (1), financial report (2), sales process (3), pricing (4), marketing mix (5)). We also measured to what extent their corporate experience has helped to understand and acquire the course curriculum. (confidence from “1 absolutely not” to “5 greatly helped”).

Table 2 shows the measures and the headcount indicators of the students’ experiences. The results show more and deeper experience among dual students (dual student indicator in all topics 41, confidence 30, and traditional student indicator 18, confidence 10).

**Table 2.** Prior knowledge of business topics (N = number of positive answers, C = sum of the confidence values, the indicator values are headcount proportional values)

| | 1 | | 2 | | 3 | | 4 | | 5 | | All | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | C | N | C | N | C | N | C | N | C | N | C |
| All students | 14 | 50 | 3 | 7 | 15 | 52 | 12 | 43 | 7 | 25 | ***51*** | ***177*** |
| All students indicator | 44 | 31 | 9 | 4 | 47 | 33 | 38 | 27 | 22 | 16 | ***32*** | ***22*** |
| Dual student | 10 | 38 | 3 | 7 | 11 | 41 | 11 | 40 | 4 | 18 | ***39*** | ***144*** |
| Dual student indicator | 53 | 40 | 16 | 7 | 58 | 43 | 58 | 42 | 21 | 19 | ***41*** | ***30*** |
| Traditional student | 4 | 12 | 0 | 0 | 4 | 11 | 1 | 3 | 3 | 7 | ***12*** | ***33*** |
| Traditional student indicator | 31 | 18 | 0 | 0 | 31 | 17 | 8 | 5 | 23 | 11 | ***18*** | ***10*** |

The second part of our research was the focus group discussion, where the participants were divided into three focus groups of 10–15 students. First we reviewed the work place experience of the participants. As mentioned earlier among the 32 students were 19 first year dual students, who had at least a half year workplace experience at their dual company. The dual training was the first workplace experience for 21% (N = 4) of the dual students. The others 79% (N = 15) had other previous experience, mainly summer jobs at enterprises not in connection with their learned profession (work in a kiosk, movie ticket inspector etc.) There was only one student with absolutely no previous work experience. 92% (N = 12) of the non-dual students also had some short term work experiences.

After the introductory question the focus group discussion went on to find out how the company experience helped in understanding the subject of corporate economics and which areas were discovered by the student at the company. The dual students reported about their first term experience, when they spent a few days shadowing at different departments at their company, understanding the company structure and had an overview of the context of the operation of the organizational units. Financing, quality assurance, project management, procurement, design, assembly, production, sales, market research, customer searching, customer relations, logistics, pricing, preparation of quotations were the most mentioned areas, where dual students had experience at their dual company. Non dual students had less experience at their short term summer student workplace, they had no overview of the operation of the business they worked for.

We also examined what results the students achieved in the academic course of Business Economics. Dual students performed better in the 1 to 5 scale (“1 insufficient” to “5 excellent”): dual students’ achievement 3.8, non-dual students’ achievement 2.7.

## 5 Conclusion

In our research we intended to capture the differences of learning the entrepreneurship topics among dual and non-dual students. We used different parallel quantitative and qualitative methods, such as the questionnaire and focus group interviews to discover the main characteristics of obtaining this knowledge. Our hypothesis was that business experience makes a difference in acquiring the knowledge. This hypothesis has been supported by the research results. Students having real experience in the entrepreneurial sphere had a better understanding of the entrepreneurial process, they had a more complex overview and deeper understanding.

The dual study model is quite new experience in the Hungarian Higher Education. The first two years have proven the expected results, but the topic needs continuous further research.

## References


1. Tóth, P.: Theoretical Foundations of Corporate Mentor Training. Obuda University, Budapest (2015)
2. Melin, G., et al.: Towards a future proof system for higher education and research in Finland. Publications of the Ministry of Education and Culture, Finland (2015). http://www.minedu.fi/OPM/Julkaisut/2015/liitteet/okm11.pdf. Accessed 14 July 2016
3. Kovacs, Z.S., Török, E.: Dual system for renewing Hungarian higher education. Int. J. Educ. Learn. Syst. **1**, 81–85 (2016)
4. Yu, L.: Research on the cooperative education model cultivating in higher vocational education. Educ. Manage. Eng. **1**, 35–41 (2012)
5. Simonics, I.: Seminar organization, planning and management. In: Tóth, P. (ed.) Theoretical Foundations of Corporate Mentor Training, pp. 53–73. Obuda University, Budapest (2015)
6. Educatio: Research and development related to the implementation of the dual training programs, analysis of Hungarian and foreign practices as a good examples. Case studies. Educatio Nonprofit Kft, Budapest (2014)
7. Göhringer, A.: University of cooperative education–Karlsruhe: the dual system of higher education in Germany. Asia Pac. J. Coop. Edu. **3**(2), 53–58 (2002)
8. Burns, C., Chopra, S.: A Meta-analysis of the effect of industry engagement on student learning in undergraduate programs. J. Technol. Manage. Appl. Eng. **33**(1), 2–20 (2017)
9. OECD: Knowledge Management in the Learning Society, OECD Publishing, Paris (2000). http://dx.doi.org/10.1787/9789264181045-en. Accessed 03 May 2017
10. Lave, J., Wenger, E.: Situated Learning: Legitimate Peripheral Participation. Cambridge University Press, New York (1991)

# Serious Games for Reading Acquisition: A Tentative Prototype

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**Abstract.** In this paper preliminary results obtained with a prototype game developed for spelling training are presented. The game is played using an Android tablet and a joystick connected with it via Bluetooth, allowing the user to directly interact. Although in an early stage, the authors believe this approach to have a high motivational potential due to its interactivity with the child undergoing the training. The prototype was tested with second graders. All the children were highly motivated to play the game and the joystick use clearly increased their level of interest. The development of this serious game seems to be a promising approach to early intervention on spelling and reading acquisition difficulties.

**Keywords:** Reading and spelling acquisition · Early intervention
Serious games

## 1 Introduction

Early intervention is critical for reading and spelling acquisition difficulties. For early intervention to be possible, at risk children must be identified using reading and spelling difficulties predictors. At risk children are those who, during preschool years, reveal difficulty with phonemic awareness development and letter sound knowledge. Those children should be subject to early intervention, before or early at the beginning of formal reading acquisition, thus preventing them to experience learning difficulties [1–3]. Learning difficulty is in itself negative as it prevents the child to experience success, but it is also worth mentioning that it is associated with other negative consequences such as low motivation, retention and school dropout [4].

Accompanying the mainstream class environment with one teacher allocated to 20 to 26 children (in the Portuguese system) is a hard task for at risk children who instead respond well to systematic and one-to-one intervention [5].

The most promising reading programs in what regards the learning results are those that combine phonological awareness explicit training with highly structured reading instruction (e.g., [6, 7]). More specifically, it is important to intervene on the


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phonological awareness deficits and to introduce systematic and explicit teaching of letter sound and word recognition [8]. Although the reading and pre-reading skills are identified and well known, the mainstream class usually fails on at risk children, as they are not given enough opportunities to acquire letter sound knowledge that would later support the normal reading competencies development (e.g., [1]).

Educational software has been considered to be a highly valuable resource for these cases, as it has the potential to adapt to each individual learning rhythm. Indeed, education software has long been adopted and supported by research (e.g. [9–19]) although up until the first decade of this century there were some methodological issues that may have biased the (positive) results, such as the absence of a control group and follow up studies. In [3] an intervention study was performed with Graphogame – a software intended to help at risk children to acquire reading skills –, willing to overcome those limitations, thus including a control group and a follow up study. In [3] Graphogame was administrated to Finnish children identified as at risk of developing difficulties in reading acquisition. After the intervention there was a significant progress in terms of letter knowledge, reading and spelling skills. In addition, about sixteen months after the intervention, children presented reading and spelling accuracy and fluency skills similar to the rest of the classroom.

Portugal followed the tendency to adopt educational software despite some initial approaches lacked a controlled evaluation of the impact of their use. The recent Portuguese adaptation of Graphogame (Portuguese Foundation Graphogame) goes against this tendency, as the impact of the training was monitored, regarding reading skills development [20].

The adaptation of Graphogame for Portuguese and the positive results obtained with at risk first graders has exposed the need of another type of complementary game, with a more interactive nature and with a more pronounced focus on spelling, given the existing comorbidity between reading and spelling problems. Indeed, most of the software and serious games focus on reading skills although spelling difficulties (in the form of orthographic errors) are a serious symptom, which tends to accompany dyslexic throughout their lives [21].

In this paper preliminary results obtained with a prototype game developed for spelling training are presented. Although in its earlier stages, the authors believe this approach to have a high motivational potential due to its interactivity with the children undergoing the training.

## 2 Method

### 2.1 Participants

Ten Portuguese speaking 2$^{nd}$ graders played with the prototype, for ca. 10’ within the school context. Table 1 presents the age and gender of the students that tested the prototype. All participants were enrolled in a reading and spelling intervention program, for having been identified as at risk for learning difficulties.

**Table 1.** Participants characterization (age and gender)

| Participant | Age (years; months) | Gender |
|---|---|---|
| #1 | 7; 3 | M |
| #2 | 7; 5 | M |
| #3 | 7; 0 | M |
| #4 | 7; 5 | M |
| #5 | 7; 6 | F |
| #6 | 7; 10 | F |
| #7 | 6; 11 | F |
| #8 | 7; 8 | F |
| #9 | 7; 9 | M |
| #10 | 7; 8 | F |

## 2.2 Material and Procedure

The game is played using an Android tablet and a joystick connected with it via Bluetooth, allowing the children to directly interact. The game can be started by clicking on an Android app symbol, similarly to any other common Android application. The joystick has a cylindrical shape and detects motion via a 6-axis Inertial Measurement Unit – cf. Fig. 1. Its simple form and robust construction make it ideally suited for young children. The connection between the tablet or other Android device and the joystick can be performed in a very easy way by the teacher clinical/parent accompanying children. When the game is launched, the application developed in this work searches for Bluetooth devices and presents a list of devices found. The teacher/clinical/parent must then choose the label corresponding to the joystick. No further configuration is necessary.

**Fig. 1.** Joystick for children use

The game underlying goal is the training of five simple disyllabic words – CV.CV (C for consonant; V for Vowel) with one complex grapheme, i.e., one sound represented by more than one letter; e.g., < ch > in < chat >. The prototype was developed with one visual scenario, which consists of a piggy bank in a farm as seen in Fig. 2.

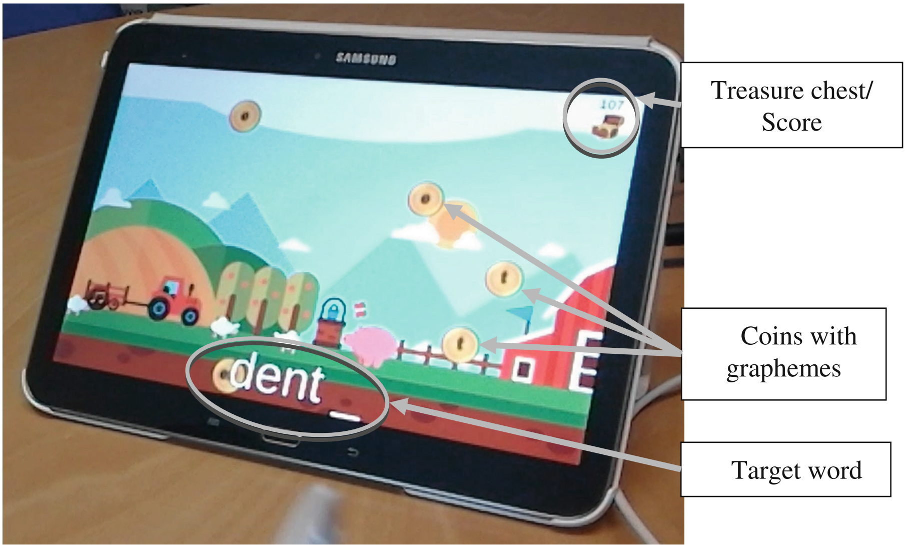


**Fig. 2.** Screenshot of the game

Before start playing, the teacher/clinical/parent accompanying children must make a very simple oral introduction on how the game works. Since the game dynamics is very simple, children present no difficulty in this step.

This piggy bank is fed by golden coins, each with a grapheme (one or two letters, corresponding to one sound). The game starts with a verbally presented word along with the presentation of four dashes. Each dash will contain a grapheme of the target word when the game is complete (cf. Fig. 2). After listening to the target word, the child is required to select the appropriate graphemes (in the correct order) to spell that word. Letters contained in the coins continuously fall from the top of the screen, whereas the piggy bank is at the bottom (cf. Fig. 2); the child's task consists on moving the piggy bank in order to avoid "catching" the wrong graphemes and to "catch" the correct ones. The child interacts with the screen using the motion sensitive joystick connected via Bluetooth. The child is given immediate corrective feedback after each grapheme selection. If the correct grapheme is selected the child hears a cash register sound – positive reinforcement – and the grapheme is stored; if the selection is incorrect, there is no sound and the grapheme is not stored.

Additional behavioral modification strategies were adopted by using a punctuation system that at the same time may be used as positive reinforcement and response cost. At the beginning of the game the child has 100 points indicated at the right upper corner of the screen, within a treasure chest (cf. Fig. 2); each correct selection is followed by bonus punctuation whereas each incorrect selection corresponds to punctuation withdrawal.

## 3 Results

All the children were highly motivated to play the game and the joystick use clearly increased their level of interest. The prototype is yet to be improved in what regards the motion sensitivity as well as the Bluetooth connection. Results obtained in the trials are presented in Table 2.

**Table 2.** Results: average number of errors per word on the grapheme selection.

| Participant | Average number of grapheme selection errors per word |
|---|---|
| #1 | 2 |
| #2 | 1 |
| #3 | 3 |
| #4 | 3 |
| #5 | 4 |
| #6 | 5 |
| #7 | 3 |
| #8 | 4 |
| #9 | 2 |
| #10 | 6 |

## 4 Conclusion

The development of reading difficulties predictors is of upmost importance in preschool years, so that early intervention occurs before or early at the beginning of formal reading acquisition. To this end, this study presented preliminary results on the development of a prototype consisting of a tablet game controlled by a simple and robust joystick. The development of this serious game proved to be a very promising approach as children were highly motivated to play it. This motivation was assessed by visual inspection of children reactions when playing the game and by the spontaneous and very positive informal feedback given by children after playing the game. The prototype must suffer technological improvements, not only regarding the playability obtained but also regarding communication issues. Future studies will also test the impact of the game in terms of students' effective learning. To this end, future works will test two groups of children. One of the groups will play the game in a regular basis in a given period of time and the other one (the control group) will not. Both groups will be assessed using reading acquisition tests at the beginning and at the end of the study, so that the actual benefits of the game developed in this work can be quantified.

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## References

1. Hatcher, P., Hulme, C., Snowling, M.: Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. J. Child Psychol. Psychiatry **45**(2), 338–358 (2004)
2. Wimmer, H., Mayringer, H.: Dysfluent reading in the absence of spelling difficulties: a specific disability in regular orthographies. J. Educ. Psychol. **94**(2), 272–277 (2002)
3. Saine, N., Lerkkane, M.K., Ahonen, T., Tolvanen, A., Lyytinen, H.: Computer-assisted remedial reading intervention for school beginners at risk for reading disability. Child Dev. **82**(3), 1013–1028 (2011)
4. Lyytinen, H.: State-of-science review: SR-D12 New technologies and interventions for learning difficulties: Dyslexia in Finnish as a case study. In: Foresight Mental Capital and Wellbeing Project: The Government Office for Science. Goverment Office for Science, London, UK (2008)
5. Torgesen, J.: Recent discoveries from research on remedial interventions for children with dyslexia. In: Snowling, M., Hulme, C. (eds.) The Science of Reading: A Handbook, pp. 521–537. Blackwell, Oxford (2005)
6. Hatcher, P., Hulme, C., Ellis, A.: Ameliorating early reading failure by integrating the teaching of reading and phonological skills: the phonological linkage hypothesis. Child Dev. **65**(1), 41–57 (1994)
7. Hatcher, P., Hulme, C., Miles, J., Carroll, J., Hatcher, J., Gibbs, S., Smith, G., Bowyer-Crane, C., Snowling, M.: Efficacy of small group reading intervention for beginning readers with reading-delay: a randomised controlled trial. J. Child Psychol. Psychiatry **47**(8), 820–827 (2006)
8. Lovett, M., Barron, R., Benson, N.: Effective remediation of word identification and decoding difficulties in school-age children with reading disabilities. In: Swanson, L., Harris, K., Steve, G. (eds.) Handbook of Learning Disabilities, pp. 273–292. Guilford, New York (2003)
9. Blok, H., Oostdam, R., Otter, M., Overmaat, M.: Computer-assisted instruction in support of beginning reading instruction: a review. Rev. Educ. Res. **72**(1), 101–130 (2002)
10. Elbro, C., Rasmussen, I., Spelling, B.: Teaching reading to disabled readers with language disorders: a controlled evaluation of synthetic speech feedback. Scand. J. Psychol. **37**(2), 140–155 (1996)
11. Jiménez, J., Hernández-Valle, I., Ramírez, G., Rossario, M., Rodrigo, M., Estévez, A., O'Shanahan, I., García, E., Trabaue, M.: Computer speech-based remediation for Reading disabilities: The size of spelling-to-sound unit in a transparent orthography. Span. J. Psychol. **10**(1), 52–57 (2007)
12. Magnan, A., Ecalle, J.: Audio-visual training in children with reading disabilities. Comput. Edu. **46**(4), 407–425 (2006)
13. Soe, K., Koki, S., Chang, J.: Effect of computer-assisted instruction (CAI) on reading achievement: a meta-analysis. In: Pacific Resources for Education and Learning, pp. 3–25 (2000)

14. Wise, B., Ring, J., Olson, R.: Training phonological awareness with and without explicit attention to articulation. J. Exp. Child Psychol. **72**(4), 271–304 (1999)
15. Ronimus, M., Kujala, J., Tolvanen, A., Lyytinen, H.: Children's engagement during digital game-based learning of reading: the effects of time, rewards, and challenge. Comput. Edu. **71**, 237–246 (2014)
16. Ecalle, J., Kleinsz, N., Magnan, A.: Computer-assisted learning in young poor readers: the effect of grapho-syllabic training on the development of word reading and reading comprehension. Comput. Hum. Behav. **4**, 1368–1376 (2013)
17. Girard, C., Ecalle, J., Magnan, A.: Serious games as new educational tools: how effective are they? A meta-analysis of recent studies. J. Comput. Assist. Learn. **29**, 207–219 (2013)
18. Boyle, A., Hainey, T., Connolly, T., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., Pereira, J.: An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. Comput. Edu. **94**, 178–192 (2016)
19. Arnab, S., Lim, T., Carvalho, M.B., Bellotti, F., de Freitas, S., Louchart, S., Suttie, N., Berta, R., De Gloria, A.: Mapping learning and game mechanics for serious games analysis. Br. J. Edu. Technol. **46**, 391–411 (2015)
20. Sucena, A., Silva, A., Cruz, J., Viana, F.: Portuguese foundation graphogame: preliminary results. In: Proceedings of the 17th European Conference on Developmental Psychology, 2016, pp. 259–262 (2016)
21. Maughan, B., Messer, J., Collishaw, S., Pickles, A., Snowling, M., Yule, W., Rutter, M.: Persistence of literacy problems: spelling in adolescence and at mid-life. J. Child Psychol. Psychiatry **50**(8), 89–901 (2009)

# Effectiveness of Traditional Laboratory Classes to Learn Basic Concepts of Electric Circuits: A Case Study

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**Abstract.** The main goal of the study here reported is to measure the effectiveness of hands-on laboratory classes to learn basic concepts of electrical circuits. Pre- and post-test methodology is used as an instrument to evaluate knowledge gain. Students of a Chemical Engineering Course answered conceptual tests covering three different electric circuits' contents before and after performing the laboratory experiments. The results show that a significant change in the number of correct answers occurs in less than half of the questions. Overall, the normalized gain is low. Some significant differences were found in the performance of female and male students in pre- and post-tests. However, there is no such difference in the normalized gain. The results are discussed taking into account the instructional environment, the framework of the course and of the engineering program where the experiments took place.

**Keywords:** Laboratory classes · Electric circuits · Concepts · Pre- and Post-tests Gender gap · Knowledge gain

## 1 Introduction

The role of laboratory experiments in science and engineering programs has always been a very important topic of discussion in education research [1–7]. This research tries to understand how experimental activities contribute to meaningful learning and the achievement of the established goals in science and engineering education [4, 8].

One of the objectives of introductory physics courses is to enhance student understanding of basic physics concepts. It is well known and recognized that Physics is a topic where students show some difficulties in problem solving and specially in understanding the concepts and evoking them when solving problems [9–13]. There are a number of studies devoted to evaluating the impact that undergraduate laboratory classes have on some of the learning outcomes specific to experimentation or to higher order thinking skills [14–17]. However, not many of them focus on conceptual knowledge gain [18]. The fact that concepts are usually introduced in main lectures and are also referred to in problem solving classes, may provide an explanation, since it is thus difficult to isolate the specific impact of the experimental activities on conceptual knowledge gain.


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Several tests with multiple choice conceptual questions serve as instruments to measure conceptual knowledge in different areas of undergraduate Physics, the most used and notorious one being the Force Concept Inventory [9]. These tests are constructed so that they assess the most common misconceptions (for an overview see [19]). They have been thoroughly validated and have been used in the context of pre- and post- test methodology, serving in many cases as instruments to measure the effectiveness of the instructional strategies [20].

The main goal of the present study is to evaluate the impact in conceptual knowledge gain of traditional electrical circuits' hands-on experiments, using as measure the results in pre- and post-tests. These classes are traditional in the sense that students, working in group, are guided through the procedures, register and analyze data and discuss the results answering to some given open questions. The conditions in which the laboratory classes took place were ideal to isolate the experimental activities as the only cause of change in pre- and post-test results.

Some studies indicate a tendency for male students outperforming female students in conceptual physics tests [22–25]. One of the goals of the present study is to make a preliminary diagnosis of this gap in the topic of electric circuits within an engineering program where the female students outnumbered the male students.

In Sect. 2, the learning objectives of the experimental activities are stated, the conditions in which the laboratory classes took place are described, the methodology in the implementation of pre- and post-tests is explained and the analysis of the results is outlined. The results are presented in Sect. 3 and discussed in Sect. 4. The conclusions are presented in Sect. 5.

## 2 Description of the Case Study

The Chemical Engineering program has 4 courses of laboratory experiments. Within the second of these courses, occurring in the 6th semester, there is a modulus devoted to electrical circuits' experiments. The main goals of these experiments are to

- Develop skills in using digital multimeters and a breadboard to measure basic electrical quantities, such as current, voltage, resistance, capacity;
- Understand the basic concepts of resistive direct current (DC) circuits, RC direct current circuits and RLC alternate current (AC) circuits;
- Collect, analyze and interpret the experimental results;
- Use the oscilloscope to observe voltage signals as a function of time.

All of the theoretical contents of this experimental activities are covered previously in an introductory Physics course occurring in the 4th semester of the Chemical Engineering program. To make a revision of all these contents and prepare the students for the laboratory experiments, six hours of lectures were delivered.

Students had three laboratory classes of 3 h each, in a total of 9 h. Each of the three classes cover a different electric circuits' content: the first one concerns basic laws of direct current resistive circuits; the second, the charge and discharge of a capacitor in a direct current RC circuit and the third concerns the study of frequency dependence of impedance, voltage and current in a RLC circuit powered by an alternate voltage source. The laboratory classes were conducted in a traditional way. A given procedure was followed and all the measurements, analysis of the data and discussion of the results were registered in a form sheet that was graded later.

To assess if performing the experiments had impact on basic conceptual knowledge of electric circuits, a pre- and post-test methodology was implemented. Before each class and after the revision lecture, students answered a test with multiple choice conceptual questions. The first test consisted of fifteen questions taken from DIRECT, a standard test developed to assess misconceptions of direct current resistive circuits [21]. The time to complete this test was twenty minutes. The second test lasted fifteen minutes and consisted in eight questions about charge and discharge of capacitors in an RC circuit. Finally, the third test took ten minutes and had five questions focused on the dependence on frequency of impedance and phase difference in a RLC circuit. Five weeks after the first laboratory class and two weeks after the last, students answered a post-test with twenty-eight questions, twenty-six of which were the same they had answered before, fourteen questions from the first test, seven from de second and all of the questions from the third pre-test.

The conceptual tests accounted for only 20% of the mark, whereas the preparation and the report of the experiment accounted for the remaining 80%.

The tests were constructed so that the most important concepts of the electric circuits concepts addressed in the experiments were covered.

Analysis of the tests' results can be outlined as follows:

- The averages in pre- and post-tests where calculated for the total number of students and separately for female and male students.
- The overall normalized gain for the class was calculated using [20]

$$\langle g \rangle_{\text{class}} = \frac{\langle post \rangle - \langle pre \rangle}{100\% - \langle pre \rangle} \tag{1}$$

where ⟨pre⟩ and ⟨post⟩ stand for the average percentage of correct answers in the three pre- and post-tests, respectively.

- The individual normalized gain was calculated.
- The Mann-Whitney statistical test was used to check for differences in the results of male and female students in pre-tests, post-tests and in normalized individual gain.

The McNemmar non-parametric statistical test was performed in order to distinguish the questions where a significant change occurred due to the experiments.

## 3 Results

The number of students performing the first pre-test was 60, the second 77 and the third 73. Overall, 80 students answered to the final test, 28 of which were male and 52 female students. Since the number of students that answered both pre- and post-tests is different for the different laboratory classes, it is more convenient to analyze the results of the three tests separately. Also, the number of questions differs in each test. Moreover, they cover different conceptual aspects of electric circuits. The results depicted in Table 1 show that male students performed better in the pre-tests and in two of the post-tests.

**Table 1.** Percentage of correct answers in pre- and post-tests

| Test | Questions | Pre\|total (N = 69) | Post\|total (N = 80) | Pre\|female (N = 46) | Pre\|male (N = 23) | Post\|female (N = 52) | Post\|male (N = 28) |
|---|---|---|---|---|---|---|---|
| 1 | 14 | **43.1%** | **56.7%** | **39.7%** | **49.7%** | **53.4%** | **62.8%** |
| 2 | 7 | **60.6%** | **71.4%** | **59.7%** | **62.6%** | **70.0%** | **74.0%** |
| 3 | 5 | **38.4%** | **57.0%** | **37.0%** | **40.7%** | **60.0%** | **52.8%** |

In the calculation of the normalized gain using expression (1), only the scores corresponding to students who performed both pre- and post- tests were considered. Those correspond to N = 69 students for test 1, N = 77 students for test 2 and N = 73 students for test 3.

Table 2 shows the percentages of correct answers in pre- and post-tests, for both genders, and the corresponding normalized gains. According to the literature [20], a normalized gain lower 0.35 is considered to be low. The gain is low in every test, the lowest being for test 1.

**Table 2.** Percentage of correct answers in pre- and post-tests and in normalized gains.

| | Total (%) | | <g> | Female | | <g> | Male | | <g> |
|---|---|---|---|---|---|---|---|---|---|
| | Pre % | Post % | | Pre % | Post % | | Pre % | Post % | |
| Test 1 (N = 69) | **42.4** | **56.5** | **0.24** | **38.9** (N = 46) | **53.0** (N = 46) | **0.23** | **53.0** (N = 23) | **63.7** (N = 23) | **0.23** |
| Test 2 (N = 77) | **60.7** | **72.5** | **0.30** | **59.6** (N = 51) | **70.9** (N = 51) | **0.28** | **62.6** (N = 26) | **75.8** (N = 26) | **0.35** |
| Test 3 (N = 73) | **38.4** | **57.3** | **0.31** | **37.0** (N = 46) | **60.0** (N = 46) | **0.36** | **42.0** (N = 46) | **53.0** (N = 27) | **0.19** |

To analyze whether the difference in the performance of female and male students had statistical significance the Mann-Whitney U test was performed for every test scores, pre- and post-tests, considering only students that performed both tests. The results are collected in Table 3.

**Table 3.** Comparison of female and male averaged score in pre- and post-tests

| | Pre % | | Significance Mann-Whitney U | Post % | | Significance Mann-Whitney U |
|---|---|---|---|---|---|---|
| | Female | Male | | Female | Male | |
| Test 1 (N = 69) | **38.9** (N = 46) | **53.0** (N = 23) | **p < 0.05** | **53.0** (N = 23) | **63.7** (N = 23) | **p < 0.05** |
| Test 2 (N = 77) | **59.6** (N = 51) | **62.6** (N = 26) | **p > 0.05** | **62.6** (N = 26) | **75.8** (N = 26) | **p > 0.05** |
| Test 3 (N = 73) | **37.0** (N = 46) | **42.0** (N = 27) | **p > 0.05** | **42.0** (N = 27) | **53.0** (N = 27) | **p > 0.05** |

The individual gain was also computed using (1), this time around with individual pre- and post-tests results. No significant gender differences were found in individual gains.

In order to find out for which of the questions there was a significant change in the number of correct answers between the pre to the post-test, a table of matched pairs of responses like Table 4 was constructed for every question.

**Table 4.** Example of table of results in pre- and post-tests for one of the questions

| | Post\|Correct | Post\|Incorrect |
|---|---|---|
| Pre\|Correct | A = 17 | B = 8 |
| Pre\|Incorrect | C = 35 | D = 13 |

In this table:

– *A/D* is the number of students that answered correctly/incorrectly in both pre- and post-tests.
– *B/C* is the number of students that answered correctly/incorrectly in the pre-test and incorrectly/correctly in the post-test.

The total number of matched pairs is A + B + C + D = 73. The goal is to examine if performing the experiment activities changes the proportion of students with correct answers, for each question. In the example above, the percentage of correct answer changed from 34.2% in the pre-test to 71.2% in the post-test. In order to check if this difference is statistically significant or if it had occurred by chance, the McNemar statistical test was used. The results of the test for all questions of the three tests are depicted in Table 5. There was a significant change in the correct answers only for 38.5% of the questions, revealing that for the remaining questions the experimental activities had no significant impact in knowledge gain.

**Table 5.** Significant change in the number of correct answers

| | Total number of questions | Number of questions with significant change |
|---|---|---|
| Test 1 | 14 | 6 |
| Test 2 | 7 | 2 |
| Test 3 | 5 | 2 |
| Total | 26 | 10 |

## 4 Discussion of the Results

The results presented in the previous section give evidence that

- The average scores in pre-tests are low, in the case of tests 1 and 2, below 50%.
- There is improvement in the scores for the three tests.
- The scores in the post- tests are only passable.

- Male students performed better in all of the tests except for post-test 3, as far as averages are concerned.
- The gender difference in scores is only significant in test 1, both for pre- and post-tests.
- The overall normalized gain is low according to the accepted interpretation of this quantity.
- There is no significant difference between female and male individual normalized gains.
- The experimental activities had a positive and significant impact on the number of correct answers for 10 of the 26 conceptual questions, which corresponds only to 38.5% of the questions.

There are many reasons that may contribute to the low conceptual gains. We outline a few that, although different in nature, may impact on the learning process.

**Skills in electric circuits' experimental activities:** Students showed many difficulties in using the multimeter, especially to measure current, and in constructing circuits in the breadboard that matched the schematic diagram. For many of them, it was the first time they used an oscilloscope. One of consequences was that many ammeters had to be replaced or fixed. The time spent on the issues of measurement and constructing the electric circuit on the breadboard, prevented students from reflecting more carefully on the measurements and on the results obtained. But these laboratory skills are also one of the objectives of the electric circuits' modulus. This contradiction would be solved by letting students spend time in the laboratory just to learn those basic skills.

**Number of students per instructor:** On average, there were twenty-four students, working in groups of three. Most of the times there were two instructors, but sometimes only one. It was almost impossible to address each student's difficulties.

**Context of the electric circuit experimental modulus in the Chemical Engineering Program:** Undergraduate Physics contents are usually covered in the first four semesters of Engineering Programs. Students revealed lack of enthusiasm and they expressed several times their discontent of having to perform these experiments in the context of a course that is devoted to Chemical Engineering laboratory activities.

**Low experience in answering to multiple choice conceptual questions:** At the faculty where the present study occurred, the use of conceptual multiple choice questions tests is not well established. Therefore, students show some difficulties in understanding what they're being asked and in isolating the important concept they're being asked about.

**Instructional method:** It is well established that students learn better if they are guided to inquiry about the physical phenomena they observe and if they have time to process and reflect on the concepts underlying those phenomena [10, 11, 20]. It is not possible to go through this process in nine hours of laboratory activities covering such an amount of concepts, as it was done here. Moreover, group work was not monitored, so it was not possible to tell how many students in each group were really engaged, focused and trying to learn.

## 5 Conclusions

An evaluation of the effectiveness of traditional laboratory classes to learn basic concepts of electric circuits was conducted by using a pre- and post-test methodology. Between the pre- and the post-test, students didn't attend to any other classes where the physics concepts under scrutiny in this study were used or explained. Therefore, the experiments were the only factor impacting on the differences between pre- and post-tests results. The laboratory classes were traditional in the sense that students followed a predefined procedure and had a limited time to cover all the activities. The questions in one of the tests, concerning basic concepts of direct current resistive circuits, belong to a well-established multiple choice question instrument that identifies important misconceptions. The questions in the other tests were chosen to address the concepts involved in the experimental activities.

It is clear from the results obtained that the conceptual knowledge gain is far from ideal. Several reasons that can contribute to such scenario were discussed. Several improvements that wouldn't require a complete change in the functioning of these classes or a significant increase in the instructional effort could be made. For example, having students learn online how to use a multimeter, a breadboard and an oscilloscope would increase the amount of time they could dedicate to understanding the purpose of the experiments, to relate the concepts with the observations and to analyze and reflect on the results. The methodology could be inspired in Flipped Classroom. Another possibility would be to allow students to go to the laboratory just to practice those basic skills, the disadvantage being the need for instructional surveillance.

The gender difference found in this report is in agreement with most of the existing studies that show male students outperform female students in science and engineering subjects [22–25]. However, the results here discussed indicate that the conceptual gain is not different, i.e. female students have lower prior and post conceptual knowledge, but the gain for both genders is similar.

One significant outcome of this study is that it can raise awareness of how traditional experimental activities impact on student knowledge. Moreover, analyzing in detail for which questions there was a change in performance may significantly help improving the design of the experiences and of the group activities so that the concepts addressed in those questions are conveniently highlighted.

Starting from the diagnosis, the changes that could be implemented in the instructional methodology are more likely to have the desired consequence of improving knowledge gain.

The conclusions of this study cannot be taken as definite. It would be important to repeat this study with more students, from different engineering programs, to assess the reproducibility of these conclusions.

## References


1. Kolb, D.A.: Experiential Learning: Experience as the Source of Learning and Development. Prentice Hall, Englewood Cliffs (1984)
2. Etkina, E.A., Van Heuvelen, A., Brookes, D.T., Mills, D.: Role of experiments in physics instruction - a process approach. Phys. Teacher **40**, 351 (2002). https://doi.org/10.1119/1.1511592
3. Hake, R.R.: Socratic pedagogy in the introductory physics laboratory. Phys. Teacher **30**, 546 (1992). https://doi.org/10.1119/1.2343637
4. Feisel, L.D., Rosa, A.J.: The role of the laboratory in undergraduate engineering education. J. Eng. Educ. **94**(1), 121 (2005)
5. Domin, D.S.: A review of laboratory instruction styles. J. Chem. Educ. **76**(4), 543 (1999)
6. Hofstein, A., Lunetta, V.N.: The role of the laboratory in science teaching: neglected aspects of research. Rev. Educ. Res. **52**(2), 201 (1999)
7. Hofstein, A., Lunetta, V.N.: The laboratory in science education: foundations for the twenty-first century. Sci. Educ. **88**(1), 28 (2004)
8. American Association of Physics Teachers: Goals of the introductory physics laboratory. Am. J. Phys. **66**(6), 483 (1998)
9. Hestenes, D., Wells, M., Swackhamer, G.: Force concept inventory. Phys. Teacher **30**, 141 (1992)
10. Redish, E.: Teaching Physics with the Physics Suite. John Wiley&sons (2003)
11. Mazur, E.: Peer Instruction: A User's Manual. Prentice Hall, Inc., New Jersey (1997)
12. Kim, E., Pak, S.-J.: Students do not overcome conceptual difficulties after solving 1000 traditional problems. Am. J. Phys. **70**, 759–765 (2002)
13. Leonard, W.J., Dufresne, R.J., Mestre, J.P.: Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. Am. J. Phys. **64**, 1495–1503 (1996)
14. Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., Hmelo-Silver, C.E.: Design and reflection help students develop scientific abilities: learning in introductory physics laboratories. J. Learn. Sci. **19**(1), 54–98 (2010)
15. Buffler, A., Allie, S., Lubben, F., Campbell, B.: Evaluation of a research-based curriculum for teaching measurement in the first year physics laboratory. In: SAARMSTE (2003)
16. Kung, R.L.: Teaching the concepts of measurement: an example of a concept-based laboratory course. Am. J. Phys. **73**(8), 771–777 (2005). https://doi.org/10.1119/1.1881253
17. Holmes, N.G., Bonn, D.A.: Doing science or doing a lab? Engaging students with scientific reasoning during physics lab experiments. In: Engelhardt, P.V., Churukian, A.D., Jones, D.L. (eds.) PERC Proceedings, Portland, OR (2013)
18. Wielman, C., Holmes, N.G.: Measuring the impact of an instructional laboratory on the learning of introductory physics. Am. J. Phys. **83**, 972 (2015). https://doi.org/10.1119/1.4931717
19. Bates, S.P., Galloway, R.K.: Diagnostic tests in the physical sciences: a brief review. New directions. J. High. Educ. Acad. Phys. Sci. Centre **6**, 10 (2010)
20. Hake, R.: Interactive engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. Am. J. Phys. **66**(1), 64 (1998)
21. Engelhardt, P., Beichner, R.: Students' understanding of direct current resistive electrical circuits. Am. J. Phys. **72**(1), 98 (2004)
22. Docktor, J., Heller, K.: Gender differences in both force concept Inventory and introductory physics performance. AIP Conf. Proc. **1064**, 15 (2008). https://doi.org/10.1063/1.3021243
23. Lorenzo, M., Crouch, C., Mazur, E.: Reducing the gender gap in the physics classroom. Am. J. Phys. **74**, 118 (2006)

24. Pollock, S., Finkelstein, N.D., Kost, L.: Reducing the gender gap in the physics classroom: how sufficient is interactive engagement? Phys. Rev. ST Phys. Educ. Res. **3**, 1–010107 (2007). https://doi.org/10.1103/PhysRevSTPER.3.010107
25. Miyake, A., et al.: Reducing the gender achievements gap in college science: a classroom study of values affirmation. Science **330**, 1234 (2010). https://doi.org/10.1126/science.1195996

# Friend or Foe?

## Multitasking and the Millennial Learner

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**Abstract.** Rapid changes in technology over the past two decades have provided many benefits. For many of us, the transformation to the digital age has been gradual; and, most often, welcomed. We have discovered innovative ways to make use of technology in our classes with the aim of enhancing the learning experience for our students. But what about today's students, often referred to as millennials, who have never known anything but instant access to information? Computers, smart phones, iPads, and other technologies offer their users immediate access to information. These technologies can also be seen as a significant distraction to whatever the task at hand. Could these distractions be to blame for the perception of many millennials that they must multitask in order to get everything done? Could the effects of instant access to information through the use of various forms of technology be casting a cloud on student learning? If so, does this cloud have a silver lining? The aim of this paper is to address these types of questions using survey data obtained from students enrolled in a second-level physics course.

**Keywords:** Digital age · Millennials · Multitasking
Student learning in physics · Technology and student learning

## 1 Introduction

If asked to give up our computers or smart phones, many of us would probably respond with a resounding "no way!" Many of us have become reliant on our computers and smart phones to get through our daily routines. We communicate with each other via email, we look up definitions to words using an online dictionary, and we make restaurant reservations all with the push of a few buttons on a computer, smart phone, or other electronic device. For tasks such as these, our electronic devices come in very handy and save us precious time.

Let's consider the following short example. While reading the morning news online (and perhaps enjoying a cup of coffee or tea) we come across an unfamiliar word. We immediately toggle between the news source and a Google search to look up the definition of the unfamiliar word. We instantaneously find the meaning of the word and toggle back to reading the news. As we do, we are distracted by the sound of a soft beep. This beep is our computer telling us we have some new unread emails in our


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inbox. We immediately toggle to our inbox to check these new messages. Some of these emails are work-related, some are from friends or family, some are connected to various messengers on social media, and some are unwanted spam-type messages from advertisers and the like. It takes us a few minutes and then we are again back to reading the online news. Within this short span of just a few minutes we found ourselves reading the news, looking up the definition of a word and then reading through several new emails. We have been distracted and encouraged to multitask, and we haven't really started our day yet! Without even realizing it, most of us multitask on a routine basis, for better or for worse. This is but one small example of how we have all become creatures of the digital era. We are bombarded with constant and overabundant information that comes to us in small sound bites or snippets literally every waking hour of the day. While many of us can turn off our devices and walk away from them, many of us really feel an obligation to be plugged in all the time. This perceived need to always be plugged in is particularly true for many millennials.

## 2 Literature Overview

The millennial generation has received quite a bit of attention in recent years, and not all of it has been positive. Millennials are often described as being very self-focused and individualistic. It's not their fault. They have been showered with messages received from the media, their schools, and their parents that have told them that they are special. And they believe this message with an enormous amount of self-confidence [1]. This is not to say that the millennial is spoiled, but perhaps that they have been over-indulged in some respects. In fact, Twenge argues that many young people today have to overcome many challenges that previous generations did not have to face. These challenges include huge educational debts and an increasingly competitive job market upon graduation. It is perhaps the perception of many millennials that they find themselves in positions where they are being asked to do more than previous generations were asked to do, but have less resources at their disposal to do so.

But just who is the millennial generation? While there are not firm generational cutoffs, the millennial generation typically refers to the current generation of young people, born in the 1980s and 1990s. Many titles have been given to this generation including Millennial, Generation Y (GenY), Echo Boomers, 24/7's, Generation Me (GenMe), and the iGeneration. As Twenge suggests, the use of the letter i could represent many things including the internet or the individual. Other generational references include those to the Baby Boomer generation (roughly those born between 1946 and 1964) and Generation X or GenX (roughly those born between 1965 and 1980). Those in GenX have also been referred to as Post Boomers, the 13th Generation, and the Doer's, among others.

Because GenY has been given the message over and over again that they are special, this has perhaps caused this generation to be tagged as one with an over-inflated sense of self-worth and self-admiration. For example, Twenge and Campbell note that in America, the focus on self and self-admiration has been successful in raising people's opinions of themselves [2]. They note that in fact, self-esteem is at an all-time high. The caveat here is as Twenge and Campbell suggest;

namely, that the good intentions behind self-admiration sometimes blur the line between it and narcissism. In a 2008 study involving a meta-analysis of the Narcissistic Personality Inventory (NPI), Twenge and Foster discovered that the move toward self-admiration has what they refer to as a dark side [3]. Overall, their results showed a marked increase in levels of narcissism in college students in the 2000s (GenY'ers) as compared to Baby Boomers and GenX'ers. In fact, as their study showed, the upswing was particularly steep between 2000 and 2006. These researchers note that over the last few decades, "narcissism has risen as much as obesity" [3, p. 31].

One of the significant cultural influences on those in GenY is that this group of individuals is the first to be born into and to have grown up with the explosion of the internet and other technology-based tools. These tools include much more than those just used for educational purposes. Both in and out of the classroom, GenY'ers are constantly finding themselves connected to these tools through such venues as the media (in general) and through social media applications such as texting, tweeting, Instagram, etc. This constant bombardment and access to various media applications is the norm for GenY. In fact, many don't realize that they are as plugged-in as they actually are. Being constantly plugged in provides this group of young people with numerous distractions, literally 24/7. As a result, GenY'ers routinely find themselves in front of a digital screen and constantly presented with the need to multitask, whether consciously or subconsciously. Could this constant bombardment of information be too much for an individual to consume in a given setting? Is multitasking really a choice young GenY students have or is it something they do because they feel they have no other option?

Because GenY is the first generation to have instant access to all kinds of information, some have referred to them as high speed stimulus junkies. This connotation has to do with the fact that digital information is essentially available instantaneously. One might even use the analogy of a tornado – where in the midst of a tornado high winds are constantly flinging material and debris around, whether one likes it or not. In fact, recent studies have suggested that a new form of addiction, a digital one, is causing serious health-related concerns for individuals within this generation [4, 5].

The number of young people experiencing significant depression and anxiety-related disorders has also increased dramatically for those in GenY. This generation seems to be much more "stressed out" than previous generations. As part of her doctoral dissertation study involving data obtained regarding 40,192 college students and 12,056 children between the ages of 9 and 17 who had completed measures of anxiety between the 1950s and 1990s, Twenge found that when a person is born has more influence on one's anxiety level than one's individual family environment [6]. Her results revealed that students in the 1990s were 85% more anxious than those in the 1950s and 71% more anxious than students in the 1970s. Twenge also found that generational differences explained approximately 20% of the variation in anxiety, which was approximately four times more than that accounted for by the family environment. While it could be that students in GenY feel more comfortable sharing their feelings of depression and anxiety than those of previous generation, these results certainly give us cause for concern. Feelings of anxiety and depression don't go away when a student sits down to try and study for a class. Rather, they can be intensified and even exacerbated. The end result could be yet another impediment to learning, thus making students even more anxious and depressed.

Certainly not all GenY students are anxious or depressed, however the increases in those reporting problems related to anxiety and depression is alarming. While we might think that always being plugged in would be helpful, it has actually been shown to create feelings of loneliness which can then be linked to increased feelings of anxiety and depression.

Can the fact that GenY is essentially almost always plugged also be linked to increases in distraction and the perceived need to multitask? While some individuals might feel a sense of empowerment by multitasking because they feel they are getting more done, studies have shown that this is not the case. Baron suggests that for most cognitive tasks, we simply cannot concentrate on two things at once and expect to perform as well as if we had completed each task individually. She further argues that "a cascade of multitasking studies continues to indicate that one of the major issues is interruption. The intrusive stimulus breaks our concentration on the initial task at hand, and performance on that task degrades" [7, p. 218]. The bottom line is multitasking can slow an individual down and create distractions that effectively cause one to become sidetracked. Precious time is lost as one has to refocus their attention to get back on track to complete the task at hand. The example we used in our introduction is a case in point.

Moreover, could the potential links between being plugged in and multitasking be related to poorer academic performance; and, result in even greater feelings of depression and anxiety for some students? A study by Becker et al., for example, investigated whether media multitasking was a unique predictor of depression and social anxiety symptoms [8]. The study involved 318 participants that were asked to complete measures of their media use, personality characteristics, depression, and social anxiety. Their analyses revealed that even after controlling for overall media use and the personality traits of neuroticism and extraversion, higher depression and social anxiety symptoms were associated with increased levels of media multitasking. What role, if any, does the internet and the constant barrage of information often incurred through multitasking have on this generation of young GenY learners? Do internet and technology-based distractions that often go hand-in-hand with multitasking serve to impede learning? These are the types of questions that form the backbone of the current study. In this paper we will limit our focus to issues related to distractions and the perceived need to multitask and their potential connections to student learning.

## 3 Focus of Study

The present study was conducted during the spring 2017 semester with 17 students, all millennials, enrolled in a second-level, algebra-based physics course entitled Light, Sound, Action (LSA). The primary focus of the study was to determine whether these millennial students were positioning themselves, either intentionally or unintentionally, to be influenced by outside stimuli and distractors while they were studying. Through a set of anonymous questions, we asked students to respond to questions designed to elicit and uncover whether distractors were present which might, in turn, facilitate a perceived need to multitask while studying. The subsections that follow provide a brief overview of the course as well as the background of the students enrolled.

### 3.1 Course Description

The spring 2017 semester represented the second time the course had been taught under this title. Previously, the course had been taught for 15 years under the title Physics for a New Millennium. The change in title was part of an overall rebranding of the course to appeal to a wider range of students.

LSA is taught in a workshop-style format. There is a significant body of research that suggests that learning in this type of interactive environment increases not only student motivation but also enhances student learning [9–17]. Within this active learning environment, students studied the concepts of sound and waves, electricity and magnetism, and light, color, and optics. Numerous hands-on activities were interwoven throughout the course. For example, in teams of 2–3, students performed activities dealing with physics topics such as the speed of sound in air, standing waves on a string, pendulum motion, electrostatics, electric circuit function and design, and motor-building. These collaborative-based team activities were referred to as *collabs.* Considerable emphasis was placed on teamwork and team building throughout all facets of the course.

### 3.2 The Students

The 17 students enrolled varied in class level from freshman to seniors. There were 9 women and 8 men enrolled. In terms of class level, the students ranged from the freshman to senior level (4 freshmen, 7 sophomores, 5 juniors, 1 senior). There was a wide-range of majors in this class. For example, several students were either audio production or audio technology majors. Others were concentrating on such areas as business administration, film and media arts, or law and society. A few of the students have declared their intent to pursue a minor in applied physics.

The section that follows highlights a subset of the data obtained during the spring 2017 semester. For the purpose of this paper, we focus on data related to distractors that might influence students as they study; and, simultaneously encourage multitasking.

## 4 Data Collected

The data presented in this section was collected via an anonymous questionnaire given to the students toward the end of the spring 2017 semester. Students were asked a total of 7 questions. For purposes of this paper, we present data for the first 4 questions, as these are most directly linked to issues related to distractions and the perceived need to multitask while studying. The questions were designed to elicit responses that might shed some light on the role that distractors such as the students' smart phones might play in terms of student learning. Moreover, we were interested in learning whether these distractors served to encourage multitasking. If so, to what degree?

The first question asked of the students was: *In general, what form of textbook do you use in your classes (hard copies, e-books, etc.)?* A summary of the students' responses is presented in Table 1. Because students responded anonymously to the questions, each student response is identified by number. Responses are presented verbatim.

**Table 1.** Question 1: What form of textbook do you use in your classes?

| Student | Response |
|---|---|
| 1 | Usually hard textbook if I can afford it, otherwise a pdf |
| 2 | Hard copies |
| 3 | Hard copies |
| 4 | Hard copies |
| 5 | Hard copies |
| 6 | Hard copies (mostly course reserves) |
| 7 | e-books |
| 8 | I like hard copies |
| 9 | Hard copies |
| 10 | e-books |
| 11 | Hard copies |
| 12 | I scan the library textbooks and print it out or just work at the library |
| 13 | Online books |
| 14 | Hard copy that I scan for convenience – but I prefer hard copy |
| 15 | e-books |
| 16 | Hard copies |
| 17 | This is the only class I've taken which uses a textbook, so a hard copy |

**Table 2.** Question 2: How often do you use the internet instead of the textbook to answer a question?

| Student | Response |
|---|---|
| 1 | About 30% of the time (usually if I can't find an answer that I understand in the book) |
| 2 | Only when I absolutely can't figure out/fully understand the answer from the text |
| 3 | Very often |
| 4 | Very often, I would go to internet first |
| 5 | Rarely, but if the textbook is not clear |
| 6 | About 10% of the time |
| 7 | Almost always |
| 8 | I will look in the book first and then look online |
| 9 | Once every ten questions/when I'm really stuck |
| 10 | 50% of the time |
| 11 | 20% of the time |
| 12 | Rarely. I find the answers easier to understand and more accurate |
| 13 | When it's an online textbook, often but if it's a physical textbook, not often |
| 14 | If Blackboard is considered, then somewhat frequently. But book is very useful for homework |
| 15 | 25% of the time I use the internet, 75% of the time I use the textbook |
| 16 | Never |
| 17 | Very often |

The intent of this question was to ascertain whether students were using paper or electronic copies of their textbooks. If students were using electronic copies, then this would mean that they were using their computers and hence have instant access to the internet. Thus, they might be more susceptible to distractors.

The second question asked of the students was: *How often do you use the internet instead of the textbook to answer a question?* A summary of student responses is presented in Table 2. The intent of this question was to determine whether or not students were going online to seek answers to their homework questions, regardless of whether or not they were using a hard or electronic copy of the textbook. It is our position that if students were using a hard copy of the book, but still going online to access answers to questions, then they were potentially putting themselves in a position where they could more easily be distracted.

One obvious distractor for many of us, and not just our students is our smart phones. The third question posed to the students asked: *Does your smart phone play any role while you are studying?* The intent of this question was to uncover what role, if any, the students' smart phones might have played in terms of distracting them from the task at hand – namely, studying. Table 3 provides a look at the students' responses to this question.

**Table 3.** Question 3: Does your smart phone play any role while you are studying?

| Student | Response |
|---|---|
| 1 | Yes, I use it to play music on my speakers instead of my computer so I don't get distracted by music |
| 2 | Only to play music |
| 3 | I'll use my smart phone for looking up questions, and calculations |
| 4 | Yes, sometimes I use it for calculations |
| 5 | It is useful, not while studying, but in class when there is a concept I do not understand but I do not want to slow the class down I can use my |
| 6 | Smart phone to check on the concept |
| | Yes, to answer texts/messages; look up something quickly |
| 7 | Yes, for quick definitions |
| 8 | I use it as a study break |
| 9 | Yes, as a distraction |
| 10 | No |
| 11 | I use my phone to quickly look up the definition of a word |
| 12 | A distraction, sometimes a calculator |
| 13 | Yes, to play music, look at messages |
| 14 | It is my major distraction! |
| 15 | Distractions, and communicating with fellow students regarding class work |
| 16 | Yes, listening to music or other distractions |
| 17 | Just to play music or quickly Google something |

The fourth question posed was: *Do you allow for outside stimuli from your phone or computer (social media, texting) while you are studying?* The impetus for this question was to uncover whether or not students allowed for outside distractions to impinge on their study time. We hoped to learn whether or not students were allowing distractions on a regular basis which would, in turn, necessitate multitasking. This data is presented in Table 4.

**Table 4.** Question 4: Do you allow for outside stimuli from your phone or computer (social media, texting) while you are studying?

| Student | Response |
|---|---|
| 1 | Usually I can't avoid it, but it's mostly just to text my boyfriend while we both work if he's having a problem and/or to be moral support for each other |
| 2 | I try to limit it to only music |
| 3 | Yes, but I'll check texting only, just in case |
| 4 | Yes, but I usually mute it |
| 5 | No, I work with other students to avoid any want for outside stimuli |
| 6 | I try not to but it always happens |
| 7 | Only important calls (family) |
| 8 | Usually I like talking [sic] sets (like I will do a certain amout of problems before I reach for my phone) |
| 9 | Yes, but I try to cut down on it |
| 10 | Music… sometimes |
| 11 | No |
| 12 | Yes, I like being mildly distracted while I study |
| 13 | Yes |
| 14 | Yes, and I probably shouldn't |
| 15 | Sometimes |
| 16 | Sometimes, but I try to omit it |
| 17 | I don't turn my phone off, but I don't check notifications |

In the section that follows we provide a synthesis and discussion of the data presented here. In doing so, we have looked for emergent themes and common items that might distract students while studying. We are particularly interested in how technology-based distractors such as computers or smart phones might impact the students. While one could argue that there are always distractions – we maintain that students of millennial age are the first to experience these types of distractions on a regular basis. Perhaps the students' responses will allow some light to be shed on what learning is like for the millennial student. In addition, we hope to learn whether these distractions push the need for students to feel like they must multitask while learning. Given the fact that there is no direct evidence that anyone can successfully perform better while multitasking, we feel the students' responses are critical and important.

## 5 Interpretation of the Data

Our first question looked at the type of textbooks students tended to use in their classes – either hard copy or electronic. With the rising cost of tuition and books, faculty have been encouraged to consider using electronic books which are oftentimes less expensive than the hard copy versions. In looking at the student responses presented in Table 1 we find that roughly 75% of the students said they used hard copy textbooks. One concern we had was that if students were primarily using online textbooks, then they may already be setting themselves up for distractions from various internet-type sources. Our results seem to indicate that of the majority of the students prefer to use a hard copy version of the textbooks used in their classes.

The second question asked students about the frequency with which they turned to the internet to help them answer a question, the results were quite interesting. As Table 2 illustrates, 16 of the 17 students responded that they made some use of the internet when responding to questions. It appears that our concern might be justified in that the potential immediately exists for outside distractions once students find themselves using the internet.

All of the students in this study owned a smart phone. In the third question we asked the students whether or not their smart phones played any sort of role when they were studying. We left this question rather open-ended and did not intentionally ask them only about how their phones might help them when studying. Rather, we simply asked what role their smart phones might play. Upon looking at the data presented in Table 3, we note that four students responded that they use their phones to play music when they study. Seven students responded that they used their phones to look up information, to find a definition, or as a calculator. Interestingly, five students mentioned that their smart phones were a distraction – either intentional or unintentional.

Our fourth question was even a bit more open-ended and simply asked students whether they allowed for some sort of outside stimuli while they were studying. Of the students questioned, only two indicated that they do not allow for outside stimuli. However, while Student 5 answered no, that they don't allow for outside stimuli, they did say they liked to work with other students (with the intent of avoiding outside stimuli). However, we could argue that working with other students in and of itself would fall under the umbrella of outside stimuli. Many of the responses to this question tended to indicate or imply that while students did allow for various stimuli to influence them while they were studying, they felt that they should not be doing. For example, Student 6 indicated that they try not to allow outside stimuli but that it always happens. Student 9 said that they did allow for outside stimuli, but they tried to cut down on it. Student 12, however, said that they did allow for outside stimuli because they liked to be mildly distracted when they studied. So we ask – are these distractions friend or foe? In the following section we provide a brief summary and then present some questions that have emerged that we feel will be useful for future studies.

## 6 Summary and Questions for Future Studies

In our literature review we touched upon the fact that millennials are often faced with many challenges that previous generations did not have to face. For example, upon graduation many millennials are finding it difficult to find employment given the tight economic conditions of the present day. To make matters worse, many millennials are graduating from college with an astronomical amount of debt compared to students in previous generations. So for all the emphasis during their childhoods that praised their self-worth and raised their self-esteem, many are being hit with a ton of bricks upon graduation. They are simply not prepared for an increasingly completive job market. And, it's really not their fault.

While we can't draw firm conclusions based on a small group of students in a single class, we can infer that a majority of the students are routinely online, whether it be on their computers or on their smart phones, during times when they are studying. Some recognized their phones as a distraction and implied that they really should be limiting its use while they are studying.

What we do see based on the results presented is that many of the students, whether intentionally or not, are setting themselves up for outside distractions while studying. These distractions often result in students multitasking while they are studying. Since we have found no evidence thus far that performance increases while multitasking, these results are somewhat concerning. It appears that this group of students fits well within the description of the millennial we presented in our literature review. These students tend to shift quickly from one thing to another, and, some seem to do so fully aware that outside distractions might be influencing them.

There are many other issues raised in this paper, such as the validity of the material that students find on the internet and their ability to fact-check such information. We also found numerous studies relating increases in internet and technology use to a relatively recent increase in the number of students reporting that they have experienced issues related to depression and anxiety. All of these issues suggest the need for additional studies.

## References

1. Twenge, J.M.: Generation Me: Why Today's Young Americans Are More Confident, Assertive, Entitled – and More Miserable Than Ever Before. Atria, A Division of Simon & Schuster, New York (2014)
2. Twenge, J.M., Campbell, W.K.: The Narcissism Epidemic. Atria, A Division of Simon & Schuster, New York (2009)
3. Twenge, J.M., Foster, J.D.: Mapping the scale of the Narcissism epidemic: increases in Narcissism 2002–2007 within ethnic groups. J. Res. Pers. **42**, 1610–1622 (2008)
4. Kandaras, N.: It's Digital Heroin: How Screens Turn Kids into Psychotic Junkies. New York Post (2016)
5. Digital Addiction: An ABC News 20/20 Special Report, 19 May 2017. http://abcnews.go.com/2020/video/digital-addiction-2020-special-friday-109c-abc-47451357

6. Twenge, J.M.: The age of anxiety? Birth cohort change in anxiety and neuroticism, 1952–1993. J. Pers. Soc. Pyschol. **79**, 1007–1021 (2000)
7. Baron, N.S.: Always On. Oxford University Press, New York (2008)
8. Becker, M.W., Alzahabi, B.S., Hopwood, C.J.: Media multitasking is associated with symptoms of depression and social anxiety. Cyberpsychol. Behav. Soc. **66**(2), 132–135 (2013)
9. Laws, P.W.: Calculus-based physics without lectures. Phys. Today **44**(12), 24–31 (1991)
10. Beichner, R.J., Saul, J.M., Allain, R.J., Deardorff, D.L., Abbott, D.S.: Introduction to SCALE-UP: student-centered activities for large enrollment university physics. In: Proceedings of the Annual Meeting of the American Society for Engineering Education, Seattle, Washington, Session 2380 (2000)
11. Hake, R.R.: Active-engagement vs. traditional methods: a six thousand student study of mechanics test data for introductory physics courses. Am. J. Phys. **66**, 64–74 (1998)
12. Cummings, K., Marx, J., Thornton, R., Kuhl, D.: Evaluating innovation in studio physics. PER Suppl. Am. J. Phys. **67**, S38–S44 (1999)
13. Thornton, R., Sokoloff, D.: Learning motion concepts using real time microcomputer-based laboratory tools. Am. J. Phys. **58**, 858–867 (1990)
14. Redish, E.F., Steinberg, R.N.: Teaching physics: figuring out what works. Phys. Today **52**, 24–30 (1999)
15. Van Heuvelen, A.: Overview, case study physics. Am. J. Phys. **59**, 898–906 (1991)
16. Mazur, E.: Peer Instruction: A User's Manual. Prentice Hall, Upper Saddle River (1997)
17. Redish, E.F.: Teaching Physics with the Physics Suite. John Wiley & Sons Inc., Hoboken (2003)

# Enhancing a Shared-Access, Hardware-Based, Random Number Generation System

## Operating Systems FUSE File-System Development Support

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**Abstract.** High quality random numbers form a critical foundation for computing in applications such as data encryption, simulation, and modeling. Recognizing the import of random numbers we have integrated hardware-based random bit generation into a major file system project for the Operating Systems class. Originally built around background radiation events detected by a Geiger counter, we are in the process of extending this to additional hardware-based random number generators configured for shared access by student teams. This work-in-progress documents the most recent deployment of this technology.

**Keywords:** Hardware random numbers · File systems · Operating systems Pedagogy

## 1 Introduction

### 1.1 Overview

High quality random numbers form the basis for much of our modern security infrastructure, in particular data encryption and secure transmission. In addition, many simulation models rely on quality random numbers for accuracy. There are a variety of physically based random number generation approaches such as those surveyed in [1]. As part of an active-learning approach [2] we have previously reported on using background radiation as detected by a Geiger counter as the basis for random numbers to support file-systems projects in the Operating Systems class [3]. This work describes an extension of that project providing additional hardware-based random number resources configured for shared, remote access and its initial deployment.

### 1.2 The Operating Systems Class

The Operating Systems class at our university integrates operating systems principles with a variety of hands-on projects ranging from probing internal inter-process communications, re-writing scheduling algorithms, memory management, and file systems. Operating Systems is a designated senior-level capstone course in our Computer Science


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program, and a variety of experiences ranging from programming to collaborative work is expected as an attempt to consolidate student knowledge and experience. Overt attempts to make these projects as real-life as possible are encouraged since students typically take this course just prior to graduation and joining the workforce.

One of these projects is to implement, under the Linux operating system, a FUSE (File System in User Space) files system to expose hardware-based random bits to the user. This project typically takes four to five weeks, and includes regular feedback as well as semi-flipped classroom activity.

## 2 The Hardware Infrastructure

### 2.1 Existing Hardware

Figure 1 shows the original hardware interface consisting of a Geiger Counter interfaced into a cluster of four Raspberry PI computers through the GPIO interface. Background radiation events generate pulses on an interface pin in each computer which are detected and distributed to student programs through a callback interface as detailed in [3]. Students then use the relative time intervals between radiation events to generate random bits. Student home directories are NFS (Network File System) mounted so that each computer has all of the student's files available upon login. With the current generation of four-core Raspberry Pi computers we can support up to six teams of five students each on two devices without issue.

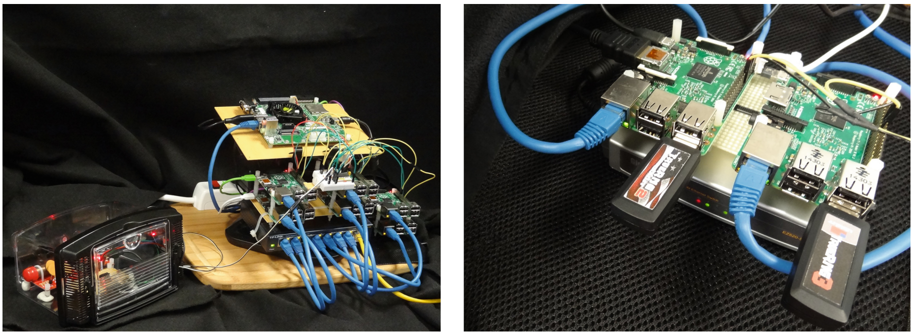

**Fig. 1.** Geiger counter (left) and TrueRNG-2 and -3 (right) random number hardware

While the Geiger counter based system has proven effective it is a relatively slow interface, typically yielding about ten to fifteen random bits per minute. This requires students to "harvest" bits 24/7 to accumulate enough to feed their files system users. Furthermore, having additional approaches to random number generation allows for comparative assignments.

### 2.2 Enhanced System

The system was enhanced by adding two USB hardware-based commercial random number generators shown in Fig. 1. Specifically, the Ubld.iT TrueRNG-2 and TrueRNG-3 [4]. Ubld.iT targets applications such as security such as SSH (Secure Shell), gaming programs such as dice, lottery, etc., statistical sampling and simulation as targets for their technology. In our application these devices plug into the USB interface, one attached to each Raspberry PI, and are made available as read-only devices to the students. Again, this is in addition to the Geiger counter system interfaced through the GPIO pins of each computer.

The TrueRNG systems derive their random bits by exploiting the avalanche effect across biased semiconductor junctions. Specifically, the semiconductor junction is biased to 12 volts then digitized. The resulting data is statistically whitened proor to being made available on the USB interface. The interface presents to the system as a serial device, and is capable of 350 kilobits/second for the TrueRNG-2, and 400 kilobits/second for the TrueRNG-3.

There are minor differences between the two models which we anticipate exploiting in future assignments. The TrueRNG-2 exhibits, according to the manufacture, a "very minor" bias when averaged over 100's of megabytes of random data. While unlikely to cause simulation or cryptographic concerns, it is statistically detectable. The TrueRng-3 device reduces this bias to below detectable levels. Having a sample of each model allows for comparative assignments to evaluate the quality of each unit as well as that of the Geiger counter output.

### 2.3 Additional Capabilities

To illustrate the output of the various hardware generators we enlist a combination of scientific visualization and statistical probes from the Fourmilab "Ent," or entropy, program. The "Ent" program produces a series of statistics over the random bits [5].

We have used a variety of visualizations for this project. For example, Fig. 2 shows the output of a real-time visualization from the Geiger counter interface in which the location and color of the squares are selected using hardware random numbers. Figure 3 exhibits the random bits as pixels in a grayscale image. Note the visual uniformity. Had there been a substantial bias it would be revealed as noticeable lines or clusters in the display.

Figure 4 shows the same information for the TrueRNG-2 and TrueRNG-3 devices. Again note the uniform texture exhibited by the random number distribution from these devices.

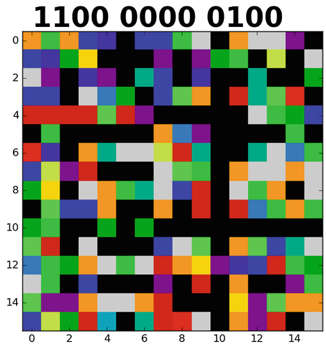


**Fig. 2.** Geiger counter random number visualization

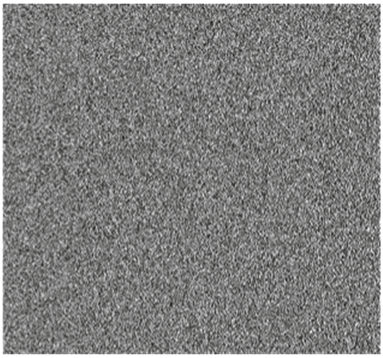

**Fig. 3.** Geiger counter random image

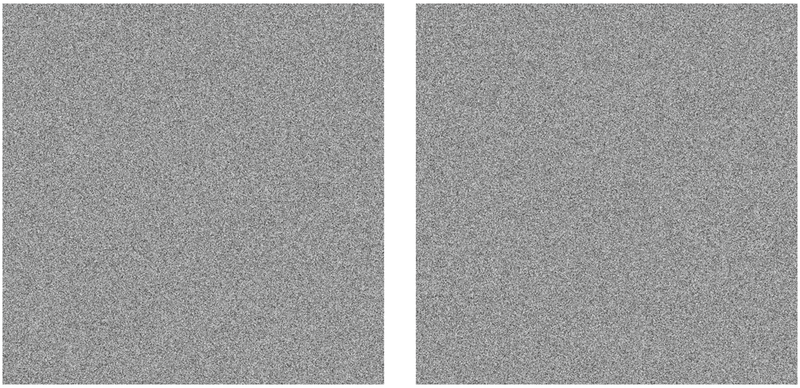

**Fig. 4.** TrueRNG-2 (right) and TrueRng-3 (left) random images

Table 1 shows the result of running the "Ent" program, which provides an indication of the quality of the random sequence from the Geiger counter pre- and post-bias adjusted as well as those from the TrueRNG-2 and TrueRNG-3 devices. The statistics include entropy, or the information density of the file. In this case the entropy is 1.0 bits/bit for all cases. Chi-square, which is particularly sensitive to sequence errors, and the arithmetic mean should approach 0.5. Pi is estimated using randomly generated points intersecting a circle inscribed in a square, and the serial correlation coefficient measures the codependence of adjacent samples.

**Table 1.** ENT random test

| | Geiger counter pre-bias removal | Geiger counter post-bias removal | TrueRNG-2 | TrueRNG-3 |
|---|---|---|---|---|
| Entropy | 1.0 | 1.0 | 1.0 | 1.0 |
| Chi-square | 0.671601 | 0.328496 | 0.53 | 0.08 |
| Mean | 0.499635 | 0.50008 | 0.4999 | 0.5 |
| Monte-Carlo-Pi | 3.458389 | 3.137899 | 3.141209 | 3.139652 |
| Serial-correlation | −0.333256 | −0.000454 | −0.00016 | −0.00004 |

The ability to compare devices opens the horizon for analytical assignments in the Operating Systems class. While the "Ent" program produces preliminary assessments there are more sophisticated random number test suites, such as those from NIST [6], allowing students to perform deeper analytics for deeper insight.

## 3 Observations and Future Work

The hardware enhancements described here were deployed late in the last semester. At that point students were already working on the Geiger counter FUSE system, and use of the new hardware was not mandatory. That said, students did try the system and informal feedback indicates that they appreciated having the faster number generator for debugging purposes, something not considered during the build out of the system. In general students expressed enthusiasm for hardware exposure and the FUSE file system project. While they find it challenging, they also recognize that it approaches a "real world" problem at an opportune time in their program.

We believe that this is the beginning of a more comprehensive hardware random number generation suite. Future plans include enhancing the devices with multiple additional hardware approaches. Under active consideration are exposing the built-in ARM random number generator on the Raspberry PI, installing the Free Software Foundation's NeuG [7] random number generator, and exploring the addition of Software Defined Radio for atmospheric noise based random numbers. We also anticipate a suite of software projects to compare the various hardware approaches.

## 4 Conclusion

The enhancement to our hardware random number generation platform expands the range of assignments appropriate for our Operating Systems students. It also stands to accelerate their development process. The resulting system forms a solid basis for future projects and holds potential for increasing awareness of the role of random numbers in their programming careers, gives them an appreciation for the limits of pseudo-random numbers, and provides experience delivering those numbers through the operating system. We believe that continuing to build out this platform enhances their intellectual horizon.

## References

1. Thomas, A.A., Paul, V.: Random number generation methods a survey. Int. J. Adv. Res. Comput. Sci. Softw. Eng. **6**(1), 556–559 (2016)
2. Arbelaiz, O., Martin, L.I., Muguerza, J.: Analysis of introducing active learning methodologies in a basic computer architecture course. IEEE Trans. Educ. **58**(2), 110–116 (2015)
3. Wolfer, J., Keeler, W.: From Geiger-counters to file systems: remote hardware access for the operating systems course. Int. J. Online Eng. **8**, 26–31 (2016)
4. Ubld.iT: TrueRNG. http://ubld.it/products/truerng-hardware-random-number-generator/
5. Walker, J.: ENT http://www.fourmilab.ch/random/
6. Rukhin, A., Soto, J., Nechvatal, J., Smid, M., Barker, E., Leigh, S., Levenson, M., Vangel, M., Banks, D., Heckert, A., Dray, J., Vo, S.: A statistical test suite for random and pseudorandom number generators for cryptographic applications. US National Institute of Standards and Technology Special Publication 800-22 revision 1a (2010)
7. Free Software Foundataion: NeuG Random Number Generator. https://shop.fsf.org/storage-devices/neug-usb-true-random-number-generator

# Comprehensive Course in Power Electronics and Its Impact on Learning Outcomes

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**Abstract.** Power Electronics plays a major role in various important and popular fields of application such as, power generation from renewable sources, electric vehicles, automation etc., especially aiding their operation at high levels of energy efficiency. The engineers specialized in power electronics have a bright future due to the possible evolution of innovative power electronic products that are cost effective with a reduction in size possible, due to the availability of highly advanced and fast acting power semiconductor devices. This mandates the requirement of highly knowledgeable and skilled manpower with an ability to cope with the quick pace of developments. Hitherto, a basic course in Power Electronics was a single traditional theory course with a lab integrated to it. This structure has undergone a change by the introduction of a comprehensive course titled Power Electronics-I in the third year of a four-year course, followed by a more advanced course titled Power Electronics-II in the final year. The newly introduced comprehensive courses have theory, lab and self-study component all integrated and each one subjected to independent assessments. The course learning outcomes for the new course are enhanced in number and redefined. This paper presents the details of the methodology adopted to enhance the learning and a comparison of the effectiveness with that of the previous model of the same course that had a limited number of course learning outcomes. The results obtained are indicative of the success and scope of the new approach.

**Keywords:** Teaching power electronics · Self-study component
Projects · Comprehensive course

## 1 Introduction

Power Electronics is emerging as one of the most important courses in an undergraduate electrical engineering curriculum, given the growing demand for power electronic engineers due to the upsurge in technological developments in the production of fast acting power semiconductor devices leading to energy efficient solutions in diverse domains. A strong ability to apply oneself is the need of the hour in engineers of today. The ability of an engineer to work in teams with contributions that are complementary from the team members towards the accomplishment of the team's goals needs attention and nurturing. The application area of power electronics encompasses multi-disciplinary domains and therefore, the development of effective


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communication skills to deliver the ideas to a diverse audience needs focus too. The teaching learning process can indeed make a profound and lasting impact in the development of individuals as professionals. Teaching the fundamentals of this course with an eye on developing the capabilities can be quite challenging and interesting for a motivated course instructor. The components of the course must expand to include activities and tasks designed from a whole new paradigm that can enable the development of various attributes in the learners. Thus, opportunities provided through a course can indeed promote motivating engineering experiences for an individual.

As stated in [1], Lectures, Laboratories, Demonstrations (live or simulated), Field experiences, Technology applications, Writing and speaking assignments, Active learning, Formal cooperative learning, Projects (design, presenting a topic) etc., do present the instructional options for course delivery. Mandatory assessments in each of these options do influence the enhancement of their capabilities and help measure their learning abilities. In [2] it is seen that self-learning is introduced for a higher level course on power electronics. In [3–8], the details of one problem statement given to the students to execute as a project leading to a new learning experience is presented.

It was noticed that only about 10% of the total students in the electrical engineering program ever ventured to take up final capstone projects in the power electronics domain. On deeper inquiry into the curriculum structure, It was seen that the students just had a basic course in power electronics in the fifth semester of an eight semester course. The course had a classical approach with theory and a defined set of lab experiments. The students were assessed for their performance only in theory and in laboratory on a predefined set of experiments. This provided limited opportunities to learn and experiment and explore with design aspects for specific applications either using a simulation package or hardware. The poor confidence level of students was attributed to their insufficient understanding and restricted exposure to application of concepts that limited their abilities to design and realize solutions using power electronic circuits. The curriculum was subsequently revised to include two courses one basic Power Electronics-I in the sixth semester and an advanced Power Electronics-II in the subsequent seventh semester both as comprehensive courses involving theory, lab and self-study component. To affirm the conclusion that, a comprehensive course can make a difference in the learning outcomes, this study presents results of evaluation of the data available at the end of the basic course in Power Electronics-I.

## 1.1 The Course Design

The contents of the course in both old and new versions of the syllabus, more or less remained the same and focused mainly on power semiconductor devices, and power converters. The course outcomes defined for the traditional course is shown in Table 1. Table 2 gives the details of the course outcomes redefined for the newly introduced course. It is seen from Table 2 that, the scope of graduate attributes has increased by the newly defined course outcomes in Power Electronics-I when defined compared to those defined in Table 1.

The National Board of Accreditation NBA, is the accrediting body for engineering institutions in India and is a signatory to the Washington Accord on Accreditation.NBA has defined a set of twelve graduate attributes that need to be measured (Table 3).

**Table 1.** Course outcomes defined for the older course on power electronics

| | At the end of the course students will have the ability to |
|---|---|
| CO1: | Identify the need for efficient conversion and control of electrical energy to match the load requirements |
| CO2: | Comprehend the characteristics of ideal switch and practically available devices with respect to its control |
| CO3: | Analyze the different types of converters like AC to DC, DC to DC & DC to AC and comprehend their steady state behaviour |

**Table 2.** Course outcomes re-defined for the Power Electronics-I course

| | At the end of the course students will have the ability to |
|---|---|
| CO1: | Explain the working, sketch the steady state and dynamic characteristics of power semiconductor devices, power converters, compare their performances, effects, derive expressions for their performance parameters etc. |
| CO2: | Formulate basic equations and estimate circuit components, power loss for given specifications of operation of power devices under steady state and dynamic conditions |
| CO3: | Apply relevant expressions to analyze the performance of power converters |
| CO4: | Independently and in a group study, collate information/data, comprehend a topic related to specific power electronics application |
| CO5: | Design, simulate and build efficient power conversion systems/subsystems for given specifications for various applications and effectively interpret the results obtained |
| CO6: | Make effective technical presentations and reports on the work carried out and communicate effectively to an audience |

The course outcomes for the new course are mapped to the graduate attributes/ program outcomes as shown in Table 4. The numbers give a measure of the strength of the mapping with ‘3’ being the strongest and ‘1’ being the mildest. This strength is arrived at as described in the later section. It is, seen from Table 2 that, course outcome one covers topics that measure their basic knowledge and understanding of the subject and is not mapped to any of the graduate attributes as indicated in Table 4, since it does not contribute to the development of attributes listed.

**Table 3.** Graduate attributes/program outcomes defined by NBA

| | |
|---|---|
| PO1 | **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems |
| PO2 | **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences |
| PO3 | **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations |

(*continued*)

**Table 3.** (*continued*)

| | |
|---|---|
| PO4 | **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions |
| PO5 | **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations |
| PO6 | **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice |
| PO7 | **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development |
| PO8 | **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice |
| PO9 | **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings |
| PO10 | **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions |
| PO11 | **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments |
| PO12 | **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change |

**Table 4.** Mapping of course outcomes to attributes

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | – | – | | | | | | | | | | |
| CO2 | **2** | | | | | | | | | | | |
| CO3 | | **2** | | | | | | | | | | |
| CO4 | | | | **1** | | | | | **1** | | | **1** |
| CO5 | | | **1** | **1** | **1** | | | | | | | |
| CO6 | | | | | | | | | | **1** | | |

**Table 5.** Assessment tools used for a continuous internal evaluation (CIE)

| Maximum CIE Marks: 50 | | | | | |
|---|---|---|---|---|---|
| | Internal tests (best 2 of 3) | Quiz-I | Quiz-II | Self-study | Lab |
| Max. Marks | 20 | 5 | 5 | 15 | 5 |

### 1.2 Course Assessment

The assessment methods used can be classified into two major categories namely, Direct and Indirect assessment. The following gives the details of their classification.

(a) Direct Assessment:

1. Continuous Internal Evaluation
    1. Best of 3 Internal Tests
    2. Quiz
    3. Laboratory test
    4. Evaluation of Student Portfolio from either self-study or any other form of alternate assessment involves performance assessment using rubrics designed for the purpose of the following
        - Assignments
        - Hardware prototypes designed to specifications
        - Simulations using computational tools.
        - Survey reports
        - Technical presentations
2. Semester End Examination (SEE)

(b) Indirect Assessment:

1. Course End Survey

Table 5 gives the list of assessment tools used for continuous evaluation of student performance and the maximum marks allocated for each in the course.

### 1.3 Analysis of the Continuous Internal Assessment of the Course

From the test papers, the quiz papers and the rubrics created for the self-study the marks covered for each course outcome in Power Electronics-I are listed as shown in Table 6. Correspondingly the weight of each course outcome on the graduate attribute/program outcome is determined. In the tests and quizzes, the students are assessed individually whereas in lab and self-study, Students work in groups of four to five and their work is assessed as a team contribution and hence the weight given to their individual assessment is less.

The following are the steps followed for obtaining the strength of the course outcome in relation to a graduate attribute.

1. The course outcomes are defined for the course so as to cover as many program outcomes as possible (four to six in number).
2. Each course outcome is defined in such a way that it maps to at least one program outcome (preferably one program outcome).
3. The strength indicated by the number used in the mapping is arrived at based on the percentage of total marks that cover the course outcome (CO) in each of the assessment tools used.

4. If the total marks that cover the CO is <25% it is given a strength ‘1’ –slight.
5. If the total marks that cover the CO is >25 to 50%, it is given a strength ‘2’-moderate.
6. If the total marks that cover the CO >50% of the total marks, it is given a strength ‘3’-strong.

Table 6 illustrates how the mapping strength is arrived for each course outcome.

**Table 6.** Assessment analysis for direct assessment through CIE

| | Marks CO1 | Marks CO2 | Marks CO3 | Marks CO4 | Marks CO5 | Marks CO6 | Total marks |
|---|---|---|---|---|---|---|---|
| Test -I | 20 | 40 | – | | | | 60 |
| Test-II | 24 | 18 | 18 | | | | 60 |
| Test-III | 30 | | 30 | | | | 60 |
| Quiz-I | 12 | 08 | | | | | 20 |
| Quiz-II | | | 20 | | | | 20 |
| Self-study | | | 03 | 03 | 07 | 02 | 15 |
| Lab | | | | | 05 | | 05 |
| Total marks | 86 | 66 | 71 | 03 | 12 | 02 | 240 |
| Percentage | 35.83% | 27.5% | 29.58% | 1.25% | 5% | 0.83% | 99.99% |
| Mapping strength to a graduate attribute | – | Mod (2) | Mod (2) | Mild (1) | Mild (1) | Mild (1) | |

## 1.4 Analysis of Semester End Assessment of the Course (Direct Assessment)

The following are the steps followed in order to arrive at the assessment values from the performance data of students in the semester end examination (SEE). In the SEE the valuation of the answer scripts is done by the course instructor and some of the scripts are evaluated by course experts from other colleges. The marks list of the SEE shows only the total score obtained by each student and the marks scored for each question is not available.

1. The questions in the question paper of the semester end examination are mapped to the respective course outcomes.
2. The total marks allocation in the question paper for each course outcome expressed as a percentage of the total marks is determined.
3. The mapping is given a strength as ‘strong’ if the marks for each course outcome is >50%, ‘moderate’ if the marks of each course outcome is between 25–50%, or ‘mild’ if the marks of each course outcome is <25% is not mapped.

Table 7 shows the how the mapping strength was arrived at from the SEE question paper. There were no design questions in the paper hence CO5 is not mapped. CO4 and CO6 are not assessed in the SEE paper and therefore are not mapped.

**Table 7.** Assessment analysis through Semester End Assessment (SEA)

| | Marks CO1 | Marks CO2 | Marks CO3 | Marks CO4 | Marks CO5 | Marks CO6 | Total marks |
|---|---|---|---|---|---|---|---|
| Semester end exam paper | 94 | 04 | 42 | – | – | – | 140 |
| % of Total marks | 67.14 | 2.86 | 30 | – | – | – | 100 |
| **Mapping Strength** | **Strong (3)** | **Mild (1)** | **Moderate (2)** | | | | |

## 1.5 Analysis of Course Assessment Through Course End Survey

A survey is conducted at the end of the course. The survey has questions that provide information on the extent of learning imparted and the questions are set to cover all the course outcomes of a course. Each question is mapped to a course outcome and the responses evaluated. A sample question and the response obtained for CO5 is as follows:

CO5: I am able to Design, simulate and build efficient power conversion systems/subsystems for given specifications for various applications and effectively interpret the results obtained.

| Grading with weight: | Excellent (5) | V. Good (4) | Good (3) | Fair (2) | Total |
|---|---|---|---|---|---|
| Responses: | 11 | 23 | 17 | 6 | 57 |

## 1.6 Determination of Course Outcome Attainment

The evaluation procedure to determine the course outcome attainment from the performance in the internal tests and quizzes and SEE is as follows. The overall weight given to course outcome attainment through CIE is 80%, through SEE is 10% and through course end survey is 10%.

1. A threshold level of 50% marks is set for a student in each of the questions.
2. The number of students who have secured $\geq 50\%$ (threshold) is expressed as a percentage of the total number of students who have attempted the question is found out.
4. The above value is given a weight based on the mapping strength for each course outcome as in Table 6. If the strength of CO is ‘3’, the weight is 100%. If the strength of CO is ‘2’, then the weight is 66.67% and if the strength of CO is ‘1’, the weight is 33.33%.

5. This value obtained is again given an overall weight of 80% and listed as the course outcome attainment obtained through direct assessment in CIE.
6. For the SEE, the number of students who have secured greater than 50% in the examination as percentage of the total number of students who have appeared for Power Electronics-I is determined. To this value, the corresponding weights of the COs are applied as mentioned in step 4.
7. The value thus obtained in step 6 is given an overall weight of 10% and listed as the course outcome attainment obtained through direct assessment in SEE.
8. For the indirect assessment through course end survey, the value for each course outcome is obtained from the weight allocated to the number of responses in each category. An example of the calculation is as follows:

| Grading with weight: | Excellent (5) | V. Good (4) | Good (3) | Fair (2) | Total |
|---|---|---|---|---|---|
| Responses: | 11 | 23 | 17 | 6 | 57 |

$$(11 * 5 + 23 * 4 + 17 * 3 + 6 * 2) / (5 * 57) = 0.7368 * 100 = 73.68\%$$

An overall weight of 10% is applied to this value obtained.

9. For the self-study evaluation, rubrics are used. Each criterion in the rubric is given three ratings namely exemplary, proficient, partially proficient and assigned corresponding weights. This is also assigned to a specific course outcome and a graduate attribute. The attainment of the course outcome is then calculated as the weighted average for that course outcome.
10. The total attainment is then obtained as given in the equation below:
Overall CO attainment = 80% of CIE (tests, quiz, lab, self-study) + 10% of indirect assessment (course end survey) + 10% of SEE.
11. The target set for the total CO attainment is 70%.

The results of the attainment obtained for Power Electronics-I by the above method is as listed in Table 8. From Table 8 it is clear that except CO1 all the other course outcomes do not meet the target specified which implies that the students' performance for questions based on lower Bloom's level is better than the ones based on higher Bloom's levels especially in the case of CO2 where questions on application of concepts.

**Table 8.** Course outcome attainment obtained for Power Electronics-I

| Course outcome | Direct assessment CIE | Weighted average CIE 80% **(a)** | Indirect assessment (course end survey) | Weighted average of indirect 10% **(b)** | Direct assessment SEE 10% **(c)** | Overall CO attainment **(a) + (b) + (c)** |
|---|---|---|---|---|---|---|
| CO1 | 69.69 | 55.75 | 76.20 | 7.62 | 6.714 | 70.06 |
| CO2 | 46.76 | 37.408 | 75.50 | 7.50 | 0.0953 | 45 |
| CO3 | 64.25 | 51.40 | 73.79 | 7.37 | 2.00 | 60.77 |
| CO4 | 74.40 | 59.52 | 84.85 | 8.48 | | 68 |
| CO5 | 73.68 | 58.94 | 53.55 | 5.35 | | 64.29 |
| CO6 | 73.45 | 58.76 | 91.89 | 9.18 | | 67.94 |

Figure 1 compares the pattern of the marks distribution/grades secured by the students during the traditional course (in 2016) and the latest in the comprehensive course (in 2017). The distribution of marks is seen to be more spread out over the different ranges in the comprehensive course. The opportunity provided through the comprehensive course to display one's ability in more than one activity and a structured assessment process in place has contributed to the spread.

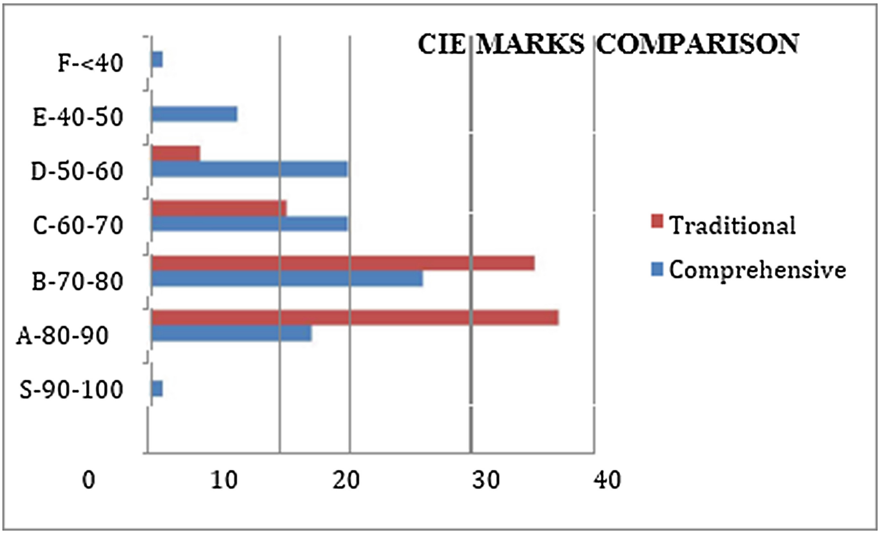


**Fig. 1.** Comparison of the CIE marks distribution between the traditional and comprehensive

## 2 The Teaching Methodology

The methodology adopted to teach the course was quite different from the traditional one where it was more teacher centric and involved the use of chalk and talk by the course instructor. In the comprehensive course, power point presentation with detailed analysis of the topics were handed ahead of the classes and they were discussed in detail in the class room through interactions and activities like think pair and share every 20 min of the class to break the monotony. The class strength was 75 with students having varied learning styles and capabilities which was evident during the interactions. The student representatives from the paired groups were encouraged to come up front and work out the solutions to problems on the board and their pictures captured and archived topic wise. Regular assignments were given to the students on each topic and were more of the following kind.

### 2.1 Sample Assignment Question

Obtain an expression for the mean power loss during turn off as well as turn off of a BJT (Bipolar junction Transistor) whose switching characteristics is as shown in the Fig. 2.

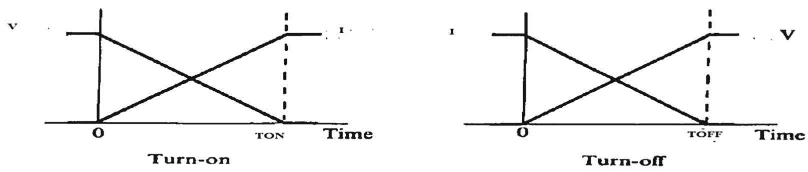


**Fig. 2.** Switching characteristics of BJT during turn-on and turn-off

Hint: v(t) during turn on is V- (V/Ton) *t; i(t) = I/Ton*t. v(t) during turn off = E = $\int_0^T v(t).i(t).dt)$.

Ans. (VI/6) *T

These kind of questions provide opportunities to students to apply their understanding of mathematical concepts to determine several parameters associated with power electronic devices.

## 2.2 Sample Questions Asked on the Lab Experiments Conducted

The students were asked to design a Uni Junction Transistor (UJT) triggering circuit for a given specification for a Silicon Controlled Rectifier SCR acting as a switch controlling the powering of a lamp load and observe the waveforms in the laboratory. They were also tested for their understanding of the operation. One of the sample questions asked on the experiment for evaluation is as given below.

1. The circuit shown in Fig. 3 is that of an Uni Junction Transistor(UJT) triggering circuit to fire the SCR. It is seen in the circuit that, the same AC supply is rectified and used to power up the UJT which is used to fire the SCR. Can the UJT firing circuit be powered up independently other than from the same power circuit? Explain., Can the resistor R1 be removed? Explain. Can B1 and B2 terminals of the UJT be interchanged? What would happen? Explain.

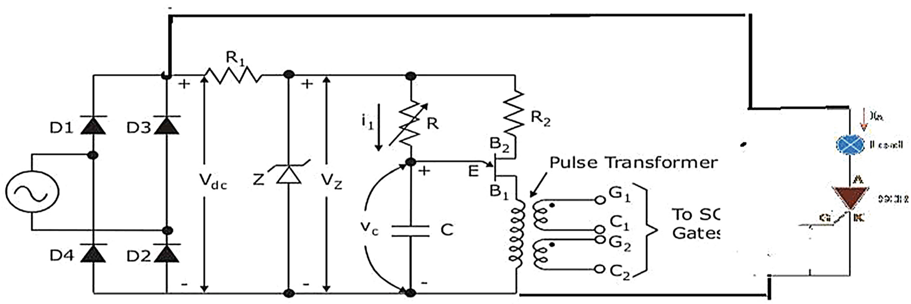


**Fig. 3.** UJT triggering circuit

To answer this question, the student needs to be conversant with the behavior of the devices used in the circuit and able to co-relate the contribution of the device construction to the functioning of the device for an application. The explanation given would be indicative of the student's depth of understanding.

2. Four power electronic devices are shown in Fig. 4. Which of the switches block voltages of either polarity (applied between terminals 'a' and 'b') when the active device is in the OFF state. Explain how.

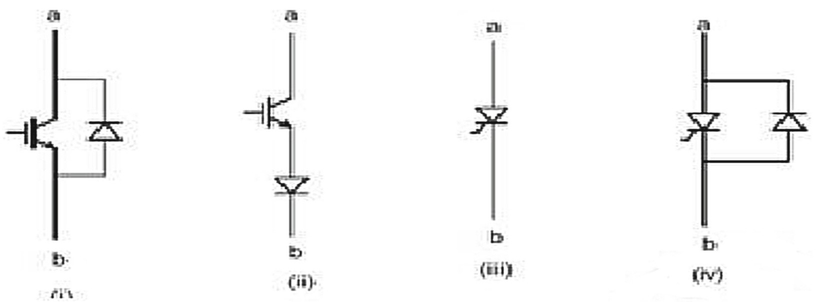


**Fig. 4.** Power electronic devices

To answer this question, the student needs to be clear about the nature of operation of each of the device. The explanation given by the student would be indicative of this.

3. For a MOSFET with Cgs = 4000 pF, the maximum gate source voltage that is allowable is 20 V. What would be the voltage that would get developed for a charge of 1 μC. Comment on this value and its impact. Suggest a remedy.

To answer this question, the student must be clear on how to apply his fundamental knowledge on the behavior of MOSFET and must be aware of the strategies through use of devices that can be used to limit the voltage levels at the gate terminals of the device.

## 2.3 Questions Based on Application of the Concepts in Test Papers/Quizzes

The following questions were asked in the internal test and quiz papers.

1. Justify why a large capacitor is necessary across the dc bus voltage of an inverter through relevant analysis.

   This requires an aptitude for mathematical analysis to justify.
2. A thyristor is gated with pulse width of 40 μs in a circuit with Vs = 100 V, R = 10 Ω and L H. The latching current of the device is 36 mA. Determine the value of L for which the device turns on.

   This requires the skill to apply circuit theory concepts to a real world application.

3. A diode in anti-parallel with the controlled switch, like IGBT, is used in VSI to:
   (a) prevent reversal of dc link current.
   (b) allow a non-unity power factor load at the output.
   (c) protect the circuit against accidental reversal of dc bus polarity.
   (d) none of the above. options

This requires the ability to eliminate all the wrong answers. It requires analytical thinking skills.

## 2.4 Self-study Component

The information was passed on to the students at the beginning of the course that, they have to collect, study, collate information related to use of power semiconductor devices with intelligent control strategies for power control based on the concepts learnt in the theory course. The application of the above must justify efficient usage of electrical energy. Students need to show specifications and the design as per the specifications. The work may also include survey and effective technical conclusions from the survey conducted. The following problems were encouraged:

1. Maximum Power Point Tracking Methods 2. Estimation of state of charge in a battery 3. Design and development of battery charger 4. Design and development of a single phase inverter 5. Design and development of single input variable output power supply.

The rubrics evolved for evaluation of the self-study component is shown in Table 9.

Some samples of the projects executed under self-study are:

1. Solar battery charger using Buck converter for a 12 V Lead acid battery suitable for a 250 W solar panel with maximum power point tracker and state of charge estimator.
2. Off line UPS system for a LCD projector.
3. A switched mode DC power supply using Buck converter to deliver 5 V, 3.3 V, +15 V, –15 V, 500 mA.
4. A charge control system using Cuk converter.
5. Studies on battery management
6. Feasibility study on solar power harvesting on campus.
7. Wireless mobile charger
8. Design of single phase full bridge inverter 230 V, 1 kW
9. Maximum power point tracking system using a Cuk converter for a 250 W solar panel

Some of the projects were built using hardware and the others were successfully simulated for their intended functionality using Matlab, LABVIEW software. Figure 5 shows a DC power supply developed by a group using hardware. Students were encouraged to present their work through posters made for the purpose.

**Table 9.** Rubrics for self-study evaluation

| Criteria | Exemplary | Proficient | Partially proficient | Max points |
|---|---|---|---|---|
| Demonstration of working of prototype/simulation for its intended operation, (CO5) (PO3, PO4, PO5) | Very clear and free in operation during the demo and completed the intended task (3) | Moderately clear and fairly responsive to questions and answers, intended task not fully complete (2) | Moderately clear and fairly responsive to questions and answers, intended task not fully complete (1) | /5 |
| Response to Q & A and able to collate information regarding a topic related to specific applications (CO4: PO4, PO12) | Highly responsive to questions asked and has clarity (2) | Moderate response and clarity (1) | Fair response. Not very clear (0.5) | /3 |
| Analysis of the problem (CO3, PO2) | Has carried out the analysis and is able to summarize and arrive at valid results (3) | Has moderately carried out the analysis and has an idea about the results arrived at (2) | Fairly aware of the analysis done and the results obtained (1) | /3 |
| Presentation of results and discussions (CO6, PO10) | Well presented with clarity of thought and well defined outputs and comparisons (2) | Moderately presented (1) | Fairly presented (0.5) | /2 |
| Team Work (CO4, PO9) | Contribution from the individual complements the work of the team (2) | Moderately contributed to the work of the team (1) | Fairly contributed. Not worked as a team member (0.5) | /2 |
| | | | **Total** | **15** |

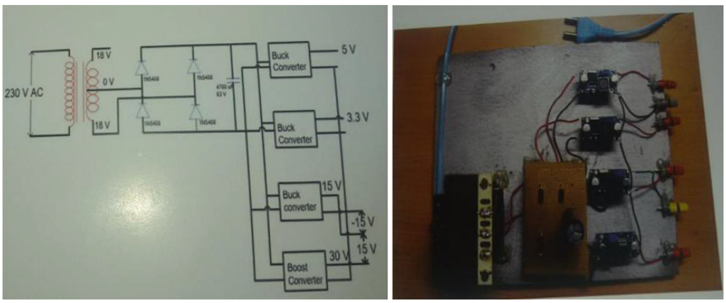


**Fig. 5.** Circuit diagram & hardware realization of a 230VAC to a variable DC Power Supply

## 3 Conclusion

It is seen that a comprehensive course does provide opportunities to the students to develop various skills including that of design and development using simulation tools. They learn to select and work on devices and components, making effective technical presentations and reports and learn to communicate their findings to a diverse audience. The course outcomes have increased in number and hence, the span of the graduate attributes. It is seen that, the course outcome attainments for CO2 and CO3 are less than the target of 70%. This is attributed to the changes brought in to the question paper patterns which required reasoning. The attainment of CO5 though did not reach the target value, it indicates a good effort from the students to develop and arrive at effective designs and reveals that there is much scope for improvement. This opportunity was completely missing in the traditional course. The question paper patterns do sets the students to think and get grounded in the application of the fundamental concepts and bring forth a wide span of thinking patterns. The students tend to get grounded in fundamental concepts that prepare them to face an advanced comprehensive course in Power Electronics-II. A review of the performance of students suggests the following that could be taken up next time. To Improve the performance of students it is proposed to conduct regular short on line tests at the end of a chapter and include that marks for grading. It is proposed to set more questions testing their application and design ability in the test papers so as to improve the strength of CO-PO mapping. Finally, to assign more marks for seminars, presentations and team work and modify the scope of the rubrics used to benefit the course outcome evaluation.

## References

1. Rashid, M.H.: Why, What and How of teaching power electronics. In: Proceedings of 2004 First International Conference on Power Electronics Systems and Applications (2004)
2. Fernão Pires, V., Pires, A.J., Dias, O.P.: Self-learning as a tool for teaching power electronics. In: 5th IEEE International Conference on e-Learning in Industrial Electronics (ICELIE) (2011). http://ieeexplore.ieee.org/document/6130035
3. Riehl, R.R., Covolan Ulson, J.A., Andreoli, A.L., Alves, A.F.: A new approach for teaching power electronics in electrical engineering courses. In: 2014 17th International Conference on Electrical Machines and Systems (ICEMS) (2014). http://ieeexplore.ieee.org/document/7014109
4. Zhang, Z., Hansen, C.T., Andersen, M.A.E.: Teaching power electronics with a design-oriented, project-based learning method at the Technical University of Denmark. IEEE Trans. Educ. **59**(1), 32–38 (2016)
5. Bonho, S., et al.: Teaching power electronics with engineering interdisciplinary projects. In: 2015 IEEE 13th Brazilian Power Electronics Conference and 1st Southern Power Electronics Conference (COBEP/SPEC). IEEE (2015)
6. Baltic, M., Krneta, R., Rakić, A.: Interdisciplinary project bridges the gap in electrical engineers' knowledge of modern control applications. Int. J. Electr. Eng. Educ. **51**(3), 203–216 (2014). Manchester University Press, ISSN 0020-7209 (Print), 2050-4578 (Online). Online date: Tuesday, September 23, 2014

7. Campos-Delgado, D.U., Espinoza-Trejo, D.R.: Educational experiments in power electronics and control theory: D.c. switched power supplies. Int. J. Electr. Eng. Educ. **47**(4), 430–447 (2010)
8. Batista, F.A.B., Petry, C.A., Santos, E.L.F., Almeida, B.R.: Didactic system for digital control of power electronics applications. In: Proceedings of 2009 Brazilian Power Electronics Conference (COBEP 2009), Bonito-Mato, Grosso do Sul, Brazil, 27 September–1 October 2009, pp. 1093–1098 (2009)

# The Development of ICT Tools for E-Inclusion Qualities

## Work in Progress

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**Abstract.** With the diversity and increasing use of different information and communication technologies (ICT) in the educational sector, new pedagogic approaches are also being introduced and have had a major impact on the educational sector, focusing on different perspective including improved educational methods and in both schools and homes, information and communication technologies (ICT) are widely seen as enhancing learning, fulfilling their rapid diffusion and acceptance throughout developed societies. But the need to utilize ICT tools to support and guide educators in finding the right support for students with special individual needs is still a challenge, investigating different challenges that are presented to teachers in their working environment is an ongoing matter. One of these challenges that teacher face frequently is creating an inclusive environment. An "inclusive education" is a process of strengthening the capacity of the education system to reach out to all learners involved. It changes the education in content, approaches, structures and strategies, with a common vision that covers all children of the appropriate age range. Inclusion is thus seen as a process of addressing and responding to the diversity of needs of all children. Therefore an inclusive education system can only be created if schools become more inclusive, in other words, if they become better at educating all children in their communities with their individual needs. Therefore, creative forms of communication should be encouraged to promote personalized care, hence the focuses of this research is to investigate the use of data process flow map with the aim to guide the teacher towards an inclusive way of thinking.

**Keywords:** Information and communication technologies · Inclusion
Education system

## 1 Introduction

The utilization of ICT tolls has been investigated and introduced in many studies in different context. The potential of social inclusion and exclusion that technology can offer, and the way in which technology can facilitated to access information sources, learning opportunities and personal agencies can be investigated [1]. The World Declaration on Education for All, adopted in Jomtien, Thailand (1990) [2], sets out an overall


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vision: universalizing access to education for all children, youth and adults, and promoting equity. This means being proactive in identifying the barriers that many encounter in accessing educational opportunities and identifying the resources needed to overcome those barriers [2]. Flexible teaching-learning methodologies necessitate shifting away from long theoretical, pre-service-based teacher training to continuous in-service development of teachers [2]. A survey regarding ICT in education was commissioned in 2011 by the European Commission Directorate General Communications Networks, Content and Technology to benchmark access, use of and attitudes to ICT in schools in the EU27, Croatia, Iceland, Norway and Turkey, the conducted survey investigating the use of ICT in education. More than 70% of teachers surveyed at all grades expressed a positive or very positive opinion about the relevance and positive impact of ICT to support different students' learning processes (working collectively, autonomously, practicing, etc.) and objectives (motivation transversal skills, higher order thinking skills, etc.) [3]. The possibility of people participating in the Information and Knowledge Societies is dependent on the availability and affordability of ICTs and relevance of contents and services, but also on their accessibility: 'users must be able to perceive, understand and act upon ICT interfaces' [3].

The objective of this study is to investigate the utilization of Information and Communication Technologies (ICT) in creating a digitalized process that can assist educators in finding the right support for pupils with special individual needs, were generalized teaching methods cannot be applied and student needs are challenging to recognize. ICT is a particularly valuable tool for children with special needs and can improve their quality of life, reducing social inclusion and increasing participation.

The aim of the platform is to guide the teacher towards an inclusive way of thinking, creating a balance between three main factors, which are the student, the environment and associated activities, resulting in full participation which is the main concept for this research project to create an inclusive environment for every child with special educational needs, creating a unified model for inclusion.

## 2 Background and Method

This study is part of a European project where the objective of the research is to utilize the Index of inclusion as a mind map, several associates are involved, including a Municipality representing Sweden as strategic partnership, together with municipalities in Germany and Iceland. The project involves different education schools (pupils aged 8–18), primary schools (pupils aged 5–12) and secondary schools (pupils aged 11–18). The average age of pupils involved in the project is 9.5 years in the primary school and 14.5 in the secondary. The overall project focus is to learn from each other by sharing experiences of the inclusion work carried out in each country, hence teachers act as a gateway and their skills development and curriculum resources need increased support.

The fact that the drive towards equity in education through the support of accessible ICT is a main concept hence is the main research goal in this project. The focus of this paper, is to create an ICT tool "Digi-Flow" that can assist educators to find the right support for students with special educational needs. The goal is to create an ICT tool

"Digi-Flow" in such a way that can help determine what is best for children with special needs. It is important to focus on creating an optimum learning environment so that all children can learn and achieve their individual potential. Therefor the research approach for this project was done via a collaborative teaching environment working with different educators with different pedagogic backgrounds that emerged during which proved to be a positive side effect of the collaboration. The process of exchanging information between groups, increases knowledge of the study group, and this experience, by helping to widen perspectives and provide accurate knowledge about the study group involved.

During this process the term "full participation" was identified during this research as a main pedagogic goal to create inclusion qualities, creating a unified model for Inclusion. In order to achieve this three main factors where identified, which are the student, the environment and associated activities.

By using a Scrum-agile approach it helped identify the main users of the tool in addition to different usability requirements and characteristics which lead to creating an initial prototype, this approach also helped to verify and identify new and changed requirements. During several different sprints were able to identify several main concepts used to create a unified model for inclusion between all associated partners, which helped create the main functional requirements of the ICT tool "Digi-Flow".

With the concept of "Full participation" as core requirement, the objective of the ICT tool is to help the teacher investigate and determine the different factors to assess and create a statically overview of the main factor for an unbalance environment. Helping the teacher determine the needed actions and resources, creating an "Action plan" clarifying how to achieve balance and therefore achieving "Full participation". As shown in Fig. 1.


**Fig. 1.** Dimentions of full participation.

## 3 Result and Discussion

Several fundamental outcomes have been achieved during the early stages of this research, including a full pedagogical assessment for the Index of inclusion, benchmarking the concept of "inclusion" between all European partners, creating a unified model that can be adapted to all countries. The development of the ICT tool "Digi-Flow" was influenced by gathering different reflections and information which was collected via different investigations and surveys that where performed, giving a clearer objective for the tool and the data needed to be included.

Since the ICT platform was created with partnerships from three different European countries it was important to understand different national requirements and regulations therefore three data clusters were considered:

1. Country legal, regulatory and programmatic commitments.
2. Country capacity to implement and apply the introduced solution.
3. Country actual results for children with special needs.

The objective of this research is to create an effective platform which can help determine what is best for children with special needs, therefore the most important element is to create a logical structure of questions. The designed platform will utilize the Index of inclusion as a mind map in a unified form between all three countries, and as a design process following the Inclusion stages- process flow for the digital tool. In a previous study the dimensions of inclusion where identified and categorized into three main categories [4], which are:

1. Equivalence: the school's capability to see/recognize and understand the pupils preconditions and needs.
2. Accessibility: the school's capability to adapt teaching, localities and social community from a diversity of needs.
3. Participation: the school's capability to stimulate pupils to 'take part'; learning to be lead, to lead oneself and learning to lead others.

To insure quality and effectiveness an auditing process was used during the development of the ICT tool, the main objective of this process was to confirm the different data collected and to help verify the different platform requirements and specifications during developed. Creating a more efficient and effective environment for all partners included in the project hence reduce and forms of redundancy in both the development method and data collected. The behavior of this process was integrated within the development method used, therefore had an incremental nature. As shown in Fig. 2, the audit process consist of several main stages and sub stages which are:

1. Planning: The aim of this phase was to help create a focus point, selecting specific features from a list of different requirement definitions, and to identify which requirement set to verify and develop further into specifications. Sub stages included:
   (a) Select priority from list
   (b) Review objectives
   (c) Set standard
2. Data Collection: During this phase the defined requirement sets where expressed in different data forms, reviewing the objective of the different data needed to be included and why. This was achieved via three sub stages:
   (a) Design audit
   (b) Collect data
   (c) Analyze data
3. Reporting: The objective of this phase was to verify and validate requirements that where translated into specification via prototyping via collecting feedback from all partners and participants.

4. Implementation and Monitoring: All feedback gathered in the previous stage was assessed and evaluated, redefining requirements and introducing changes when needed, and therefore reviewing initial requirement standard and creating action plans.
5. Review and Re-audit: The aim of this phase was to review all decision making and create additional plans.

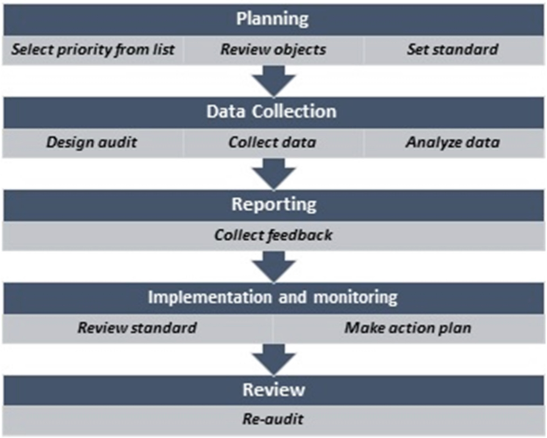


**Fig. 2.** Audit process

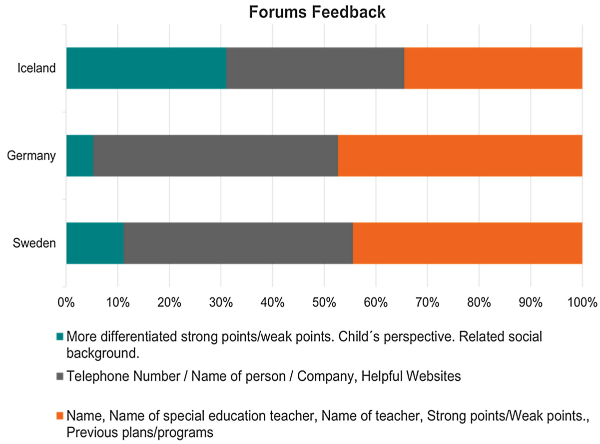


**Fig. 3.** Related information

Early results show that the need for such as tool has been confirmed, but also that the potential users for the tool can vary. Using this process also helped identify which type of data can and must be included in the ICT platform and why, such data included information regarding the child´s perspective and related social background. As shown in Fig. 3, different ideas where gathered and analyzed to help create the data sets required for the ICT tool "Digi-Flow" [4].

The results also show different user groups, indicating that the user group which found most need for such a platform are special educators, whom work directly with children with special needs on different levels. As shown in Fig. 4.

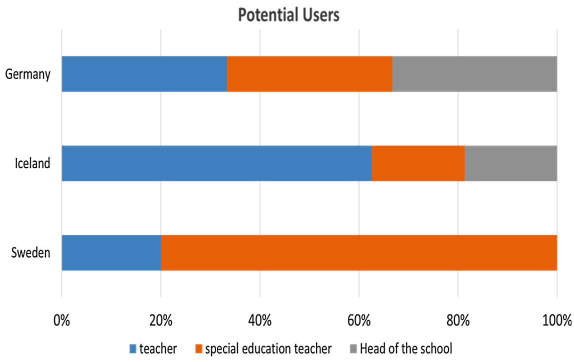


**Fig. 4.** Potential users

The study also emphasizes that the tool can be utilized as a platform to improve communication not just for the different educators working with children with special needs but also as a platform for communication between the school and parents.

The developed platform consists of different questions which are divided into categories, weights and bases. The categories are used as a factors to link resources and the bases are to filter the questions. Base in this project means two things.

1. Base-Questions (or parent-questions) can have questions depend on them, meaning sub-questions (or children-questions)
2. Base-Questions act's as the filtering process.

All questions in the system where identified, verified and validated via different survey to confirm they cover the cornerstones to attest "full participation", see Figs. 5 and 6.

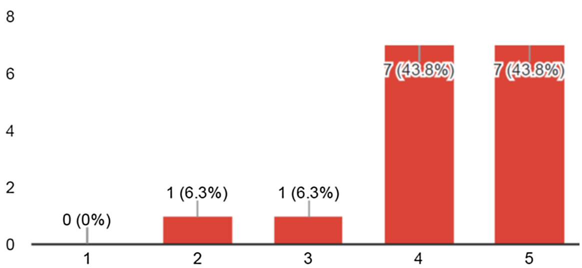


**Fig. 5.** Survey to validated used questions

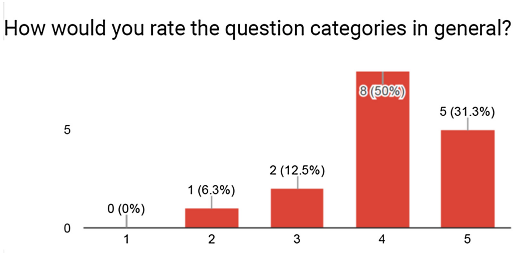


**Fig. 6.** Survey to validated and verify the categories used.

As the platform fetches a question it examines if it's a base-question. If it is, depending on the answer provided, it will identify any sub-questions linked to it. The 'weights' in this ICT platform are used to determine the importance of the questions. Weights are stored in every answers and effect the questions in a 'positive' or 'negative' way. Every question and resources are linked to a category. It maintains good structure and simplifies understanding and goal to what the objective of the question is. The main categories of full participation are displayed with a numerical representation of their relevancy to the current evaluation. The results obtained from different user groups utilizing the tool includes, a main resource page, which contains links and information of persons and country organizations that can be contacted. Additional studies and prototyping is in progress as part of this study and are part of future results verifying the advantages of ICT tools in this context. To what extent the ICT tool is spread will be measured in long-term perspectives and assessed accordingly.

## 4 Conclusion

As a conclusion, using ICT tools to link schools and different recourses can deliver substantial educational benefits, for both teachers and children with special needs. By assisting teacher in the process towards an inclusive environment helps create a sustainable and effective platform which can help determine what is best for the students and helping the teacher determine the needed actions and link resources to relevant information.

## References

1. Sheehy, K.: ICT and special educational needs: a tool for inclusion. Br. J. Learn. Disabil. **33**(4), 206–207 (2005)
2. Policy Guidelines on Inclusion in Education Published by the United Nations Educational, Scientific and Cultural Organization 7, place de Fontenoy, 75352 Paris 07 SP, France. UNESCO (2009)
3. Policy Guidelines on Inclusion in Education Published by the United Nations Educational, Scientific and Cultural Organization, p. 7. UNESCO (2013a)
4. Hussain, D.: The utilization and development of ICT tools for inclusion qualities in cases of special need children. In: Book of Industry Papers, Posters and Abstracts. International Conference on Health and Social Care Information Systems and Technologies (2016)

# Common Misunderstandings and Challenges in Learning Gauss's Law in a Junior Level Electromagnetic Engineering Course

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**Abstract.** Common misunderstandings when learning Gauss's Law in a college junior level electromagnetic engineering course are identified by observing normal course assessments and conducting one on one student interviews. Additionally, the extent to which students in this course struggle to translate prior mathematics is investigated by codifying student performance on normal assessments using a rubric developed by the authors based on Accreditation Board for Engineering and Technology (ABET) Criterion 3 (a) and (e). Five misconceptions are identified, three of which agree with physics educational literature, as well as a need for better scaffolding the translation of calculus II and multidimensional calculus material. Future work and possible intervention strategies are discussed.

**Keywords:** ABET Criterion 3 · Engineering education
Gauss's Law · Misunderstandings

## 1 Introduction

Junior level courses are when engineering students are expected to apply prerequisite material and background from chemistry, physics, and mathematics to their chosen discipline; however, there can be lingering misunderstandings or misconceptions students bring with them from these prior courses. Additionally, translating this background material to use in a new context can be an educationally challenging task. But, once students are at the junior level and admitted to an engineering program the ideal is for all students to be successful in their chosen curriculum and to remain in the program.

This work has received IRB approval IRB# x16-1616e (i053116) from Michigan State University's Internal Review Board for research with human subjects.


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According to information from the United States (US) Bureau of Labor Statistics jobs in the science and engineering sectors are growing twice as fast as the job market in general [1]. This mismatch between the demand for those with science and engineering educations and the actual supply is often colloquially referred to as the "pipeline problem". There is evidence to show that the pipeline problem for engineers in the US could be solved by retaining the students who begin engineering programs [2]. Many strategies can positively affect science, technology, engineering, and mathematics (STEM) student retention such as using active learning pedagogical strategies [2], providing additional support to under-privileged students, and promoting a more engaged and connected community [3]. In addition to these, improving educators' pedagogy by directly addressing misconceptions and scaffolding difficult tasks can improve students' performance and thereby increase their likeliness of retaining in their STEM program.

A misunderstanding or misconception is an understanding or fact someone believes to be correct (or mostly correct) but is not. These misunderstandings, sometimes also called "alternative understandings" or "naive understandings", are an active area of educational research. What conclusions students draw and how they come to them help shed light onto how knowledge or information is formed in students' mind. Misconceptions can arise from misunderstanding some given information or being given conflicting information from credible sources. In order to correct misunderstandings they need to be explicitly addressed and in order to explicitly address them, they must first be identified.

Common misunderstandings can be found in the literature for junior level courses on electromagnetics within physics undergraduate programs, but it is unclear whether these would necessarily be the same for students within engineering programs. This work seeks to identify misunderstandings when learning Gauss's Law in a junior level engineering course and to investigate students' ability to translate prior material. Therefore, addressing a need to better understand what common misunderstandings are present and to what extent students find translating pre-requisite material in to the course under study so that these issues can be directly addressed in the future.

## 2 Background

Students tend to find the study of electromagnetics, or electricity and magnetism (EM), in physics more challenging than classical mechanics [4]. It has been shown that students struggle with understanding and interpreting graphic representations of electric field lines [5] and undergraduates have been found to understand mathematics as a mechanical process and not as constructive thinking [6] which makes it difficult to understand the electric field vector in a physical context. Additionally, students are unable to transfer knowledge of the "force concept" to the "field concept" [7]. Even further, some studies have shown, using common standard assessments, that students do not demonstrate knowledge of EM a statistically significant amount more after taking a junior level EM physics course than after the freshman level EM course [8]. It is thought that the difference between students' abilities in classical mechanics and EM is because students are more able to connect with and visualize the problems posed in classical mechanics. Classic mechanics problems involve sticks, balls, cars, planes, and other examples more readily found in real life. Electromagnetics problems all involve electrons, current, voltage, fields, and other invisible things.

It is common for Gauss's Law to be one of the first concepts, if not the first, taught in junior level EM courses. Prior literature has identified common misunderstandings about Gauss's Law in junior level physics EM courses [9] including:

1. mistaking electric field and electric flux,
2. thinking electric flux and electric charge are vector quantities,
3. applying Gauss's Law to open surfaces,
4. thinking shielding applied to any bounded region and not just those bounded by a conductor,
5. confusing symmetry of an object and symmetry of a charge distribution, and
6. confusing the electric field at a point and the contribution of electric flux from an area.

## 3 Electrical Engineering Education at Michigan State

Michigan State University (MSU) offered its first electrical engineering course in 1893, in the Physics Department. Today it has an Electrical and Computer Engineering Department, housed in the College of Engineering (COE), with 833 undergraduate students (459 Electrical Engineering and 374 Computer Engineering majors respectively) as of fall 2016. MSU's engineering programs are all accredited by the Accreditation Board for Engineering and Technology (ABET), which is a non-governmental organization that accredits post-secondary education programs in "applied science, computing, engineering, and engineering technology".

In this study, we consider ECE 305, Electromagnetic Fields and Waves I, which is a required course for all Electrical Engineering majors. ECE 305 satisfies ABET Criterion 3 (a) and (e) which specify that students graduating from this program must (a) demonstrate an ability to apply knowledge of mathematics, science, and (e) an ability to identify, formulate, and solve engineering problems. As a 300-level course, it is most typically taken by students in their junior year. In addition, this course is limited to students who are admitted into the COE. This course meets for 50 min, four times per week and is taught traditionally using passive learning (lecture) with weekly homeworks and quizzes, two midterms, and a final written exam.

Broadly, this course covers the basics of Maxwell's Equations, supporting concepts such as Coulomb's Law, and the basics of time-harmonic waves and transmission lines. The first topic covered in the course is Gauss's Law, which, in addition to the constitutive relation between electric flux and electric field, allows a direct relation between electric charge and electric field, using the constitutive relation $\overrightarrow{D} = \epsilon\overrightarrow{E}$, as can be seen in Eq. 1 for a volume charge distribution.

$$\oint \overrightarrow{D} \cdot \hat{n} ds = Q_{enclosed} = \int_V \rho_v dV \tag{1}$$

Where, in Eq. 1 and the constitutive relation, $\epsilon$ is the permittivity of the medium, $\overrightarrow{E}$ is the electric field, $\hat{n}$ is the normal direction to the Gaussian surface used for the surface integral, $Q_{enclosed}$ is the total charge enclosed in the Gaussian surface, and $\rho_v$ is the volumetric charge density enclosed by the Gaussian surface. The volumetric charge density, if it is highly symmetric, can be integrated over a volume to find the total charge.

Because this topic is introduced so early, it offers a good starting point to examine how students manage the task of translating prerequisite material into the topics covered in this course as well as what misconceptions are present in learning this topic. This law is commonly first introduced to engineering track students in freshman level physics courses and more thoroughly taught in a junior level electrical engineering course. It is a particularly important idea within the discipline of electrical engineering because it is one of Maxwell's Equations, which form the basis of classical electrodynamics and circuit theory, with more well-known material such as Ohm's Law or Kirchoff voltage and current laws being a derivation from Maxwell's Equations. The overall goal for students to be able to use and recognize when to use Gauss's Law helps lead them to a broader understanding of one of the four core concepts (the four equations that make up Maxwell's Equations) that are a major part of what the electrical engineering discipline is based on.

## 4 Methods and Results

Participants in this study were recruited from the junior level electromagnetic engineering course, ECE 305 Electromagnetic Fields and Waves I, offered in the spring of 2017 at Michigan State University. A total of 48 students participated in this study, out of 58 enrolled in the course. Of the 58 enrolled there was one graduate student in the course who was not included given that the population of interest was undergraduate students, two students who enrolled in the course after the study had begun, and seven students who were absent the day the pre-assessment was administered. The demographics of the class are overwhelming represented by males of Asian or Caucasian decent. Given that it was possible that by including demographic information associated with performance student confidentiality could have been compromised, demographic data was not explicitly collected on the population nor presented in this work.

A common assessment tool, the Brief Electricity and Magnetism Assessment (BEMA), was used to evaluate students' understanding of electricity and magnetism at the beginning of the course. A rubric was developed, as can be seen in Appendix B, based on the ABET criteria the course satisfies, Criterion 3 (a) and (e), and used to codify student performance on normal assessments including two homeworks and a quiz on Gauss's Law material. Normal course assessments were observed along with one on one student interviews with six students (13% of the study population) to identify common misconceptions.

### 4.1 Pre-assessment

The BEMA assesses student understanding of basic electricity and magnetism concepts covered in college-level calculus-based introductory physics courses. It is akin to Concept Inventory (CI) tests, and has 30 multiple choice questions [4,10,11]. Similar to other CI tests, the questions on the BEMA do not require calculation but an understanding of fundamental relationships, for example, if, given some circuit scenario, a current would increase, decrease, or stay the same over time.

In a paper evaluating the validity of the BEMA, sample populations at Carnegie Mellon University (CMU) and North Carolina State University (NCSU) took the test who where demographically similar to those in ECE 305 (taken a calculus based physics course, engineering majors, taking a physics electromagnetics course that current semester) [11]. The results there showed an average pre-course BEMA scores of 23, at both CMU and NCSU, and average post-course scores of 45 and 39 at CMU and NCSU, respectively. MSU students scored on average a 35.6 an their pre-course test, the results from this study and the references study are summarized for clarity in Table 1.

**Table 1.** Results of pre-assessment (BEMA) as compared to results for comparable student populations.

| | Mean ± Standard Deviation |
|---|---|
| Pre-course (CMU + NCSU) | 23 |
| Pre-course (MSU) | 35.64 ± 13.9 |
| Post-course (CMU) | 45 ± 5.9 |
| Post-course (NCSU) | 39 ± 6 |

ECE 305 students are admitted to the COE, meaning, they have achieved a 2.0 or better in their prerequisite mathematics courses and had an overall GPA of 2.9 or better when admitted. MSU uses a 4.0 grading scale, 4.0 being the highest possible grade, where grades in classes are awarded anywhere from a 0.0 to a 4.0 in 0.5 increments. This makes a 2.0 and 2.9 grade comparable to a C and B letter grade, respectively. Additionally, a mean score of 35% on the BEMA is a very good score as compared to the others reported in the literature from comparable institutions as seen in Table 1. Overall, this implies that the average ECE 305 student has a good background in the relevant prerequisite materials.

### 4.2 Codifying Performance

The rubric used, which is based on ABET's Criterion 3 (a) and (e) can be seen in the Appendix B. The codifying scheme applied can be seen in Table 3. Applying a rubric to a performance task is an improvement to traditional grading of a problem based assessment since the interpretive nature of teachers' assessment of student's performance for mathematics, even when using a rubric, is known to vary by teacher [12]. In a survey of 75 relevant studies, its was found that analytic rubric scoring of performance tasks leads to enhanced reliability and promoted learning and/or instruction [13].

To investigate the validity of the rubric developed, the correlation coefficient between the assessments' grade when graded traditionally versus with the rubric with the first exam was calculated. Here "traditional grading" refers to grading based partially on participation, half the points for giving an honest attempt at all problems, and half the points for a correct answer. For rubric-based grading, the rubric in Appendix B was applied to all Gauss's Law problems on an assignment and the total score tallied.

**Table 2.** Correlation coefficients between homeworks and the first exam for each grading scheme.

| | Traditional grading | Rubric grading |
|---|---|---|
| HW1 & Exam 1 | 0.09 | 0.30 |
| HW2 & Exam 1 | 0.30 | 0.40 |

For both homework assignments the correlation coefficient between the graded homework and the first exam was found to be higher using the rubric than a traditional grading scheme as can be seen in Table 2. This implies that grading with a rubric, which takes into account the quality of the work and answer, is more aligned with how a higher stake assessment, such as an exam, is graded. Therefore, as has been shown in the literature, it provides better feedback to students and the instructor as to students learning. In this study, these correlation coefficients provide feedback to the investigators that the rubric performs its task reasonably well in providing a quantitative way of looking at work quality.

**Table 3.** Codifying scheme used in conjunction with the rubric.

| Category | Total | (%) | Description |
|---|---|---|---|
| Proficient | 38 | 77.6 | Score of 2 or better on all 4 rubric metrics across all assignments evaluated |
| Translational | 9 | 18.4 | Score of 2 or better on rubric metrics (1) and (2) and less than 2 on rubric metrics (3) and (4) across all assignments evaluated |
| Deficient | 2 | 4 | Score of less than 2 on all 4 rubric metrics across all assignments evaluated |

The codifying scheme binned students as being either proficient, deficient, or "translational" where students were able to identify the math or engineering topic in the problem and the correct approach but could not successfully setup the math problem they need to perform or perform the math operations successfully. Results from codifying student performance based on ABET criteria indicated that of the sample population 4% were deficient, 18.4% were translational, and 77.6% were proficient.

### 4.3 Identifying Misconceptions

By noting and grouping mistakes made from the two homeworks and quiz, which were all heavy on Gauss's Law related problems, indicated the following common misconceptions: (1) mistaking electric field with electric flux, (2) mistaking metallic boundary conditions with dielectric ones, (3) confusing the electric field at a point and the contribution of electric flux from an area, and (4) relating the electric field to only the charge present in the region of interest (where the electric field is asked to be found) and not necessarily the charge contained in the appropriate Gaussian surface.

One on one student interviews were conducted to further explore the common mistakes observed in the normal course assessments. Six students, or 13% of the study population, were interviewed. In the interviews, subjects were asked to walk the interviewer through solving a challenging Gauss's Law problem typical for the course which can be seen in Appendix A as well as the typical line of questioning. The student interviews further confirmed issues (1), (3) and (4). In the interviews the opposite of issue (2) was seen where students would treat any bound region as having metallic boundary conditions, but, the most obvious challenge for students in the interviews was a general unfamiliarity of the in-discipline language used for electromagnetics and mathematics. For example, students seemed to think that the word "shell" always indicated a metal, or attempted to solve the problem in an inappropriate coordinate system (Cartesian as opposed to spherical).

General observations from the interviews were that students' ability to approach these problems are very rote. Additionally, students were very reliant on the normally provided formula sheet in the course with five of the six interviewees asking if they would be able to have access to it during the interview. However, it did become clear that there was an incredibly underutilized ability to meta-cognate in the student population of this course. It was typical that as the students said something that was incorrect they would verbally address their mistake directly after, without any provocation from the interviewer. Thus indicating that working more meta-cognitive tasks into the course could be a possible useful educational intervention strategy. Also of note, interviewees with the highest grades, or performance, in the course used more in-discipline or connecting language. For example, they were more likely to say "electric field" as opposed to simply calling it "E" or were more likely to connect Gauss's Law to the divergence theorem in their explanations.

Between the two activities, the common misconceptions in a junior level electromagnetic engineering course as related to learning Gauss's Law are:

1. mistaking any bound region to behave like a metal,
2. mistaking electric field and electric flux,
3. confusing the electric field at a point with the contribution of electric flux from an area,

4. relating electric field to the charge present in a region as opposed to that contained in a Gaussian surface,
5. and treating metal boundaries as a dielectric.

Of the summarized common misconceptions, three have been previously identified in physics education literature [9], items (1)–(3), and two of which, (4)–(5), were not found in prior literature.

## 5 Discussion and Future Work

Students who have reached the junior level in electrical engineering have, on average, good fundamental knowledge from their prerequisite courses; however, nearly a fifth of the sample population showed clear signs of struggling to translate prior material. The authors suggest that this task of translation can be scaffolded. Additionally, we suggest that the misconceptions identified be directly addressed in the course.

A possible intervention for scaffolding students' translation would be to modify the existing homeworks. Currently, the homeworks pose problems similar to the one in the interview tool as seen in Appendix A, where a geometry and some EM quantity(s) are given and some unknown ones are asked for. We suggest that the problem should guide students through intermediary steps by having sub-questions that ask students to list the equations or relations they will need, to setup and solve for supporting quantities, such as total charge, before a larger one, such as electric field. By guiding students through the problem we can help formalize and teach a problem solving process along with providing practice.

To address the identified misconceptions, we suggest a structured, active learning, in-class activity as a possible intervention. An activity where problems that directly require addressing the common misconceptions are posed, and then student formulate a solution individually, as a small group, then discuss as a class. Based on the experiences of the one on one student interviews in this study, we believe that providing students the opportunity to discuss their thought process with peers could be very beneficial for working through their thought process and understanding of concepts.

Future work will be built on this study by introducing an educational intervention into the class to scaffold the task of translating pre-requisite mathematics material. Additionally, an educational intervention will be introduced to address the common misconceptions found. In future work, the same rubric and codifying scheme will be used in order to compare student performance and see if an improvement is observed in order to determine to what extent the intervention technique is successful. The work here allows a baseline or reference to be set for student performance and misconceptions in order to better understand the effectiveness of any future changes in pedagogy to the course.

It could also be an option to compare students' performance on this same material as taught in an equivalent physics course at MSU. However, although the Physics program covers the same material at an upper-classman level, they do not truly have a comparable course. The Physics Department covers the material from ECE 305 over the course of a full year (split between PHY 481 and 482) as opposed to a single semester, so it would require further investigation to determine if they could be considered comparable.

Additionally, if the BEMA was given as a post-assessment, correlation between performance on the BEMA and the course assessments as graded with the ABET rubric could be investigated. A positive correlation between performance could suggest a relationship between conceptual knowledge and practical knowledge for Gauss's Law problems.

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## Appendix A: Student Interview Prompt and Line of Questioning

A uniformly charged dielectric material having charge density $\rho_v = 2\ C/m^3$ and dielectric constant of $\epsilon_r = 5$ encloses a dielectric sphere with dielectric constant $\epsilon_r = 3$ as shown in the figure. The entire structure is enclosed in a charge shell of total charge $Q$, and surrounded by free space ($\epsilon_r = 1$). We are interest in $\overrightarrow{E}$ in all regions (Fig. 1).

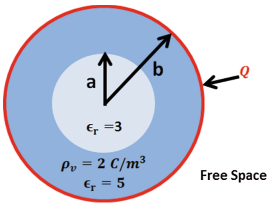


**Fig. 1.** Visualization of described problem in statement.

1. Is it clear from the description and figure what is going on in this system?
2. If you were asked to solve for the electric field everywhere in this system, what would your approach be to solve the problem. You don't actually have to solve it just list the steps for solving it.
3. Is using Gauss's Law valid for this problem? Why or why not?
4. Can you write Gauss's Law and tell me what it means? What two fundamental quantities does it allow us to relate?
5. If you were asked to find the electric field everywhere, where is everywhere? Please describe the different regions or areas in this system.
6. How would you setup the integral for the charge enclosed for each of the regions? Please write the integral setup, you don't need to take it.
7. How would you setup the integral for the Gaussian surface each of the regions? Please write the integral setup, you don't need to take it.
8. Would there be no electric field in any of these regions/spaces? Why or why not?

## Appendix B: ABET Based Assessment Rubric

| | | | |
|---|---|---|---|
| (a) Identify the mathematics, engineering, science, topics in the problem | • Identifies when a major law or formula is applicable<br>• Identifies when relations between fundamental quantities (current, voltage, etc.) can be used<br>• Identify when material property definitions can be applied | • Does not explicitly state the most applicable law in problem setup<br>• Does not explicitly state equation used for fundamental quantity relations (voltage, current, etc.)<br>• Does not explicitly state definitions or picks a suboptimal definition (one that does not quite align with the given information) | • Does not identify a major law or relation<br>• Does not identify when equations for simplification can be applied<br>• Does not identify basic quantity definitions |
| (b) Formulate an approach | • Shows coherent steps of relations between the given information and the requested information | • Shows some relevant relations | • Does not relate quantities given in the problem to those requested as final answers |
| (c) Apply this approach to the problem | • Correctly setup the necessary integrations<br>• Correctly setup other mathematical relations with the given quantities | • Sets up the integration with minor errors such as forgetting a term, incorrect sign, incorrect limits<br>• Sets up relations with minor errors such as forgetting a term or incorrect sign | • Incorrectly setup integrations<br>• Incorrectly setup mathematical relationships |
| (d) Obtain correct results | • Final answer is correct<br>• Appropriate units and vector directions are included | • Final answer has a sign error or is off by a small amount<br>• Included units or vector direction but not both were not quite correct | • No final answer or answer is incorrect<br>• No units or vector directions included |

## References


1. Dischino, M., DeLaura, J.A., Donnelly, J., Massa, N.M., Hanes, F.: Increasing the STEM pipeline through problem-based learning. Technol. Interface Int. J. **12**(1), 21–29 (2011)
2. Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., Wenderoth, M.P.: Active learning increases student performance in science, engineering, and mathematics. Proc. Natl. Acad. Sci. **111**(23), 8410–8415 (2014)
3. Tanner, K., Allen, D.: Cultural competence in the college biology classroom. CBE Life Sci. Educ. **6**, 251–258 (2007)

4. Chabay, R., Sherwood, B.: Restructuring the introductory electricity and magnetism course. Am. J. Phys. **74**(4), 329 (2006)
5. Tornkvist, S.: Confusion by representation: on student's comprehension of the electric field concept. Am. J. Phys. **61**(4), 335 (1993)
6. Nguyen, N.-L., Meltzer, D.E.: Initial understanding of vector concepts among students in introductory physics courses. Am. J. Phys. **71**(6), 630–638 (2003)
7. Furió, C., Guisasola, J.: Difficulties in learning the concept of electric field. Sci. Educ. **82**, 511–526 (1998)
8. Aubrecht, G.J., Raduta, C.: Contrasts in student understanding of simple E&M questions in two countries. In: AIP Conference Proceedings, vol. 790, no. 2005, pp. 85–88 (2005)
9. Singh, C.: Student understanding of symmetry and Gauss's law. In: AIP Conference Proceedings, vol. 790, pp. 65–68 (2005)
10. Chabay, R., Sherwood, B.: Qualitative understanding and retention. AAPT Announcer **27**(2), 96 (1997)
11. Ding, L., Chabay, R., Sherwood, B., Beichner, R.: Evaluating an electricity and magnetism assessment tool: brief electricity and magnetism assessment. Phys. Rev. Spec. Top. Phys. Educ. Res. **2**(1), 1–7 (2006)
12. Morgan, C., Watson, A.: The interpretative nature of teachers' assessment of students' mathematics: issues for equity. J. Res. Math. Educ. **33**(2), 78–110 (2015)
13. Jonsson, A., Svingby, G.: The use of scoring rubrics: reliability, validity and educational consequences. Educ. Res. Rev. **2**(2), 130–144 (2007)

# Technical Teacher Training

# Aligning Training of Teachers of Technical Institutions with Outcome Based Education

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**Abstract.** This study emphasis the need for changing design approach of training of teachers of technical institution for effective implementation of Outcome Based Education (OBE) in India and suggests student focus approach for designing teachers' training for assuring teachers support towards attainment of learning outcomes of student.

**Keywords:** Outcome Based Education · Four stage framework
Learning-teaching process

## 1 Introduction

Engineering education is undergoing through transformation from teacher-centric traditional education to learner-centric Outcome Based Education (OBE). Student engagement during instruction is a challenging task for the teachers as envisages in OBE. It is also expected that the technical institutions should be capable of producing graduate engineers with up- to- date technical knowledge and skills along with deep sense of quality, work ethics, motivation, interpersonal skills, team work skills, leadership, critical and creative thinking [1]. OBE demands learners' performance which is the product of ability multiplied by motivation, and ability is the product of aptitude multiplied by training and resources [1]. In the present context of knowledge-intensive and information-driven society, it becomes even more important for faculties to become facilitators of learning in diverse learning situations rather than merely perform teaching in a face-to face classroom situation [2]. Many instructors are unaware that alternatives exist to the traditional lecture based approach with which they were taught. Teachers believe that they are teaching appropriately but poor student performance and low ratings only reflect deficiencies in the students. Equipping engineering students with the skills needed for 21st century learners requires teaching and assessment methods not traditionally found in engineering education and unfamiliar to most engineering educators [3]. This is because, most engineering faculty members were never trained for developing those skills, but they need to create learning environment which will help their students in developing the same. Educational research already established that engineering faculty members who will be exposed to effective training with specific objectives, will be better prepared to conduct classroom teaching [3].

Most of the people learn best when they are actively involved in the learning process. Hence educators of today need to plan a thinking classroom and promote


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active learning. Group learning and collaborative exercises are exciting ways to improve classroom experience of students and thereby incorporating active learning into teaching process. OBE demands long-term, cross-curricular outcomes which are linked with learners' future life. This suggests steps have to be taken to hold great promises for reforming faculty preparatory programmes and to change of mind set and attitude amongst faculty community. Hence, there is a need for changing design approach of training of teachers of technical institutions for effective implementation of OBE in India.

## 2 Purpose

It is to be observed that, according to the information available with All India Council for Technical Education (AICTE), number of faculty members engaged in self-finance diploma level institute is nearly 1.3 lakhs and that in degree level institute is about 3.5 lakhs whereas nearly 65000 teachers are there in government financed institutes offering degree and diploma engineering programmes [4]. In-service training to the teachers of degree and diploma level technical institutions are primarily conducted by the four National Institute of Technical Teachers' Training & Research (NITTTR) in the country. In 2012–13, Ministry of Human Resource Development, Govt. of India, advised that the four NITTTR's to be ready to train approximately 80,000 polytechnic teachers within a period of six months [5], but up to the academic year 2013–2016, it is observed that only nearly 5% teachers are trained as per annual reports of NITTTRs [6–9].

Short Term Training programmes (STTPs) are presently designed by NITTTR, Kolkata for achieving three main goals viz. improvement of teachers' skills,

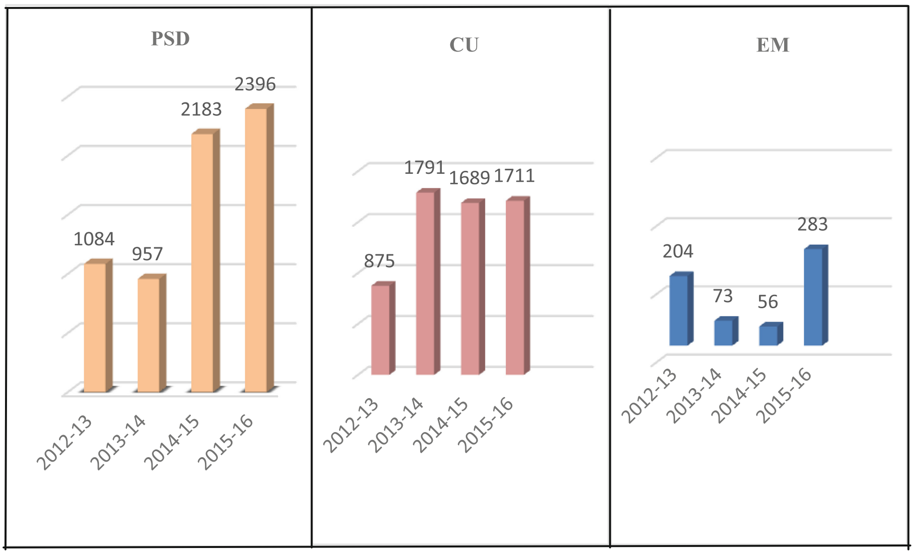


**Fig. 1.** Training data of NITTTR, Kolkata during 2012–2016

development of teachers' conceptions of teaching-learning and consequent changes in students' learning. These lead to categorise the training programmes into three major areas – (i) Professional Skill Development (PSD), (ii) Content Updating (CU) and (iii) Education Management (EM).

From the training data represented in Fig. 1, it is observed that a high enhancement rate of participation in Professional Skill Development trainings whereas training in Content Updating shows no increment during previous three years and there is an observable enhancement in Education Management areas during the academic year 2015–16.

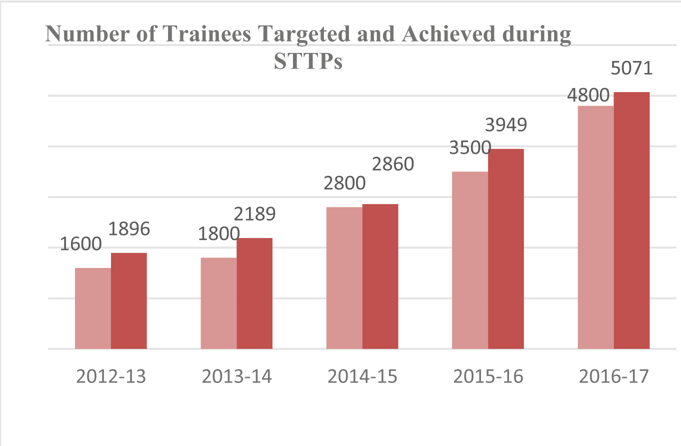


**Fig. 2.** Overall training data of NITTTR, Kolkata during 2012–2017

In the academic year 2015–16, NITTTR, Kolkata trained 5071 teachers in above mentioned areas. There is about 20% enhan-cement of overall training participation per year as revealed from the training data of last five years as represented in Fig. 2. Teachers experience during training collected through written and verbal feedback, provides a measure of trainees' reaction. It is observed that training programmes are much oriented towards developing specific knowledge of teachers in respective categories and less oriented towards improvement of student learning. This study establishes the need for integrating pedagogical aspects of teaching with content updating while designing STTPs for today's teachers.

## 3 Approach

In this paper, a four-stage framework as represented in Fig. 3, for designing a Model training programme for teachers of technical institutions has been proposed.

The pre-training stage (stage I) of four-stage framework is designed for baseline assessment of trainee teachers. In this stage, trainee's pre-requisite knowledge on specific content area related to the course along with their concept on why, what and how to teach a specific content is assessed by the trainer in a simulated classroom environment. The task of trainer at this stage is to ensure that the trainees must realise the importance of OBE and the features related to its implementation. Trainees must understand that the need for adapting the new instructional strategy, skill, or concept

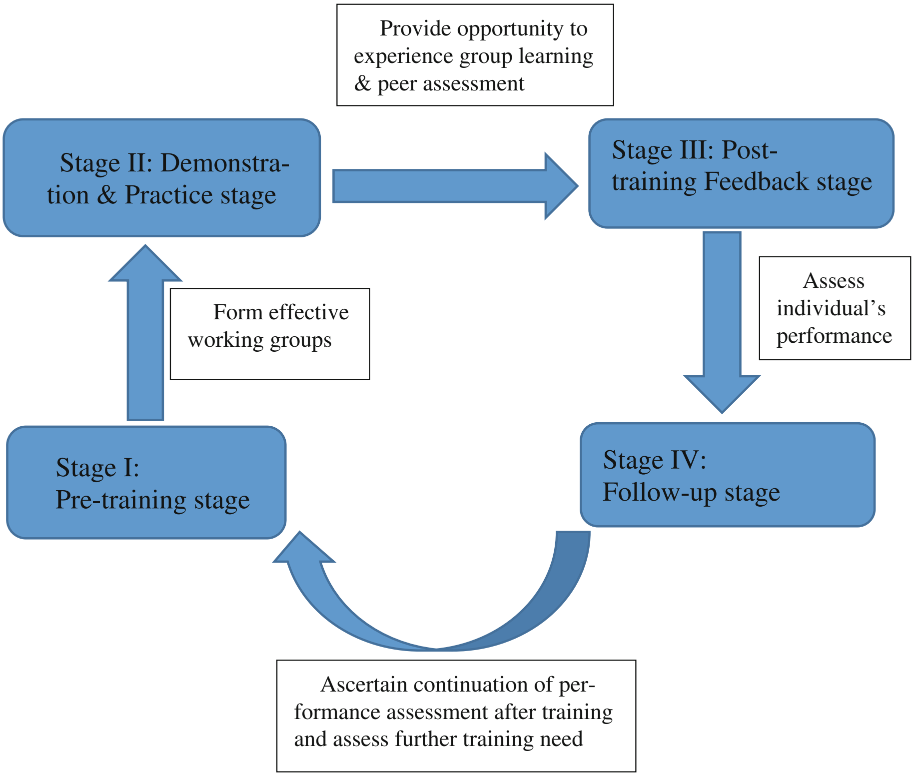


**Fig. 3.** Framework for model training programme for teachers of technical institutes

that will be presented during training are capable of enhancing student learning. The recorded observation is used for formation of effective working groups.

Stage II focuses on illustration of designing thinking classroom through collaborative exercises. It provides the trainees an opportunity to observe a model of what is being taught. The trainer demonstrates the opening action, explanation and closure of a technical content with specific Intended Learning Outcomes (ILOs) using experiential strategy. This demonstration may also be provided through a video recorded in real classroom situation. After each demonstration, the task of trainer is to illustrate the stages of instruction along with the selection of appropriate strategy. Hence this stage demonstrates mapping of sequence of instructional design to phases of learning viz. motivation, apprehension/acquisition, retention/recall and feedback/evaluation. The demonstration and illustration is followed by practice where each group is assigned with some pre-defined outcomes of the course preferably those require higher order thinking skills and asked to prepare instructional plan for active learning indicating teaching strategy, method, tools needed and estimated time. Each group then be asked to demonstrate active learning in simulated environment. Peer assessment is used for identifying strength and weaknesses of each participant groups. The trainer must then provide each trainee teacher with feedback on how well the groups and the group members have prepared and delivered plan and taken part in peer assessment. It has to be seen that the all the groups and also each group member have got sufficient time to complete the assigned task.

The stage III ensures that each trainee is able to decide course outcomes and corresponding intended learning outcomes, also able to design and deliver concerned content under the specific course and experience self-assessment. In this stage, each trainee is assigned a technical content and asked to select suitable teaching strategy and technique for promoting higher order thinking. Individual trainee's performance in the simulated classroom is video recorded which is further analysed by respective trainee for self-assessment. This helps the trainee to internalise what is being learned through group activity, observation, peer and self- assessment and trainer feedback.

In this stage training feedback is also collected on individual basis and is shared for trainees' understanding towards designing classroom teaching. The trainer need to use appropriate scoring sheet or rubric for effective training evaluation.

Stage IV deals with designing follow up activities leading to effective implementation of training in content updating. Follow up includes mainly discussion after training programme regarding issues related to implementation and need for additional training related to what is being learned. After attending the training, teachers return to their respective workplaces. They are advised to prepare instructional plan and select strategy to model for his/her class. They are advised to invite their colleague as a mentor preferably an expert in the same domain area. The mentor observes the instruction and give constructive feedback for improvement. The mentor need to be suggested to consult the trainee's video recorded during training. The feedback collected over a period of at least one month may be shared with other colleagues. For any difficulty in implementation or unpredicted outcome, trainees are advised to contact trainer for suggestion and future action.

## 4 Experimental Observation and Outcomes

The four-stage framework proposed for designing a Model training programme for teachers of technical institutions has been experimented on trial basis. A short term training programme on Simulation and Analysis of Nonlinear and Adaptive Control Systems, conducted during academic year 2016–17.

In regard to content of the training programme, control theory is an interdisciplinary branch of engineering which is concerned with the behavior of dynamical systems. It deals systems with inputs which can be controlled such that desired output can be obtained using appropriate feedback. It can be noted that as linear system obeys the principle of superposition, it can be broken down into parts and each part can be solved separately. It allows us to simplify complex problems by using several suitable mathematical tools. But in nature many things do not act in this way. Most of the systems that we observe in everyday life are nonlinear in nature and the principle of superposition fails in those cases [10]. As a result most nonlinear systems are impossible to be solved analytically using conventional mathematical tools available for linear system analysis. In addition to nonlinear control part, the content also extended to adaptive control which provide a systematic approach for automation in real time in order to maintain desired performance of the dynamic systems for unknown and/or very complex system parameters. When engineers analyze and design nonlinear dynamical systems in electrical circuits, mechanical systems, control systems, and other engineering disciplines, they need to be able to use a wide range of nonlinear analysis tools. Moreover there is increasing demands for further development of nonlinear and adaptive control theory to facilitate research activities related to study and experimentation of complex control problems [11]. This leads the engineers to formulate, analyse and design control algorithms. Thus the study of nonlinear and adaptive control systems has become important in modern – technical society and so the curriculum of electrical and electrical engineering related programmes at graduate and post graduate levels includes this as an essential course.

The pre-requisites needed for this course are knowledge of mathematics like differential equations, matrices for representing dynamic systems, signals and systems, linear control systems theory, engineering analysis and problem solving skills and social skills like work in team in handling multidisciplinary problems.

It has been observed that working groups can be identified using effective tools for baseline assessment. Pre-training activity sheet was prepared for checking of pre-requisite learning outcomes. Assessment criteria prepared for identifying 'highly prepared', 'prepared' and 'not sufficiently prepared' for the training being offered. Five groups of trainees were formed with each group consisting of 4–5 members and equally distributed category of baseline identification. The whole process was explained by the trainer so that trainees can also be able to design baseline assessment tools for their own students on related content.

Through demonstration by the trainer and then followed by collaborative exercises conducted during stage II, they understood the process of deciding students' learning outcomes based on Blooms Taxonomy table [12]. Each group designed the instruction for developing higher order thinking skills related to course content using suitable teaching strategy and method. Assignments planned in such a way that it had included all essential ILOs and it was found that sharing of working groups' thinking while designing assigned instruction had made every individual member to clear several doubts.

It was observed that practicing the whole process by individual member during stage III, many innovative ideas generated which could be implemented in conventional classroom situation but would create the learning environment active through collaborative involvement of learners. It was also found that many of the issues raised during stage II was resolved in this stage. Each trainee also prepared a self-assessment report based on their performance as recorded and shared at this stage. Feedback collected during this stage was also shared by the trainer at the time of training valediction.

Training follow-up started with evaluation of training feedback and it was found that there was appreciable enhancement in content knowledge of each individual teacher. It also gave an evidence of enhancement of teachers' self-confidence in instructional delivery and the desire to take the challenge to teach the course.

## 5 Conclusions

The suggested student focus approach in designing training programmes for teachers of technical institutes will assure attainment of learning outcomes of students with teacher as facilitator and thereby support transformation of existing teaching-learning system to a self-assessed, self-monitored learning-teaching system needed for Outcome Based Education in India.

It has been observed from the trial test of proposed framework for designing STTPs that the teachers were motivated to think independently, confident enough to take the challenge of teaching a course like Nonlinear and Adaptive Control System and also able to design innovative classroom instruction for promoting active learning.

All trainings are planned and offered by NITTTRs based on assessment of training need which is collected from teachers of the technical institutes of their respective region. But there is no systematic mechanism to ascertain continuation of performance assessment of teachers after training. NITTTR, Kolkata is now actively involved to device a system of continuous follow-up to imbibe the concept of Outcome Based Education in the country.

## References

1. Spady, W.G.: Outcome-Based Education: Critical Issues and Answers. American Association of School Administrators, 1801 North Moore Street, Arlington, VA 22209 (Stock No. 21-00488; $18.95 plus postage) (1994)
2. Kirkpatrick, D.L., Kirkpatrick, J.D.: Evaluating Training Programs, 3rd edn. Berret Koehler Publishers, San Fransisco (2006)
3. Felder, R.M., Brent, R.: Designing and teaching courses to satisfy the ABET engineering criteria. J. Eng. Educ. **92**, 7–25 (2003)
4. http://www.aicte-india.org/dashboard/pages/approvedinstitutes.php
5. F. No. 23-4/2012-TS.IV Government of India: Ministry of Human Resource Development Department of Higher Education
6. NITTTR, Annual Reports 2013–14, 2014–15 and 2015–16. Bhopal: National Institute of Technical Teachers Training and Research (2014, 2015, 2016)
7. NITTTR, Annual Reports 2013–14, 2014–15 and 2015–16. Chandigarh: National Institute of Technical Teachers Training and Research (2014, 2015, 2016)
8. NITTTR, Annual Reports 2013–14, 2014–15 and 2015–16. Chennai: National Institute of Technical Teachers Training and Research (2014, 2015, 2016)
9. NITTTR, Annual Reports 2013–14, 2014–15 and 2015–16. Kolkata: National Institute of Technical Teachers Training and Research (2014, 2015, 2016)
10. Lyshevski, S.E.: Control Systems Theory with Engineering Applications. Springer Science & Business Media, New York (2012)
11. Sastry, S., Bodson, M.: Adaptive Control: Stability, Convergence, and Robustness. Prentice Hall Information and System Sciences Series (1989). ISBN 0-13-004326
12. Anderson, L.W., Krathwohl, D.R. (eds.): A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. Allyn and Bacon (2001). ISBN 978-0-8013-1903-7

# Substantiating Standards for Training PhDs in Technical Universities of Ukraine (Case Study of the National Mining University, Dnipro, Ukraine)

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**Abstract.** The paper focuses on substantiation and implementation of the standards of the scientific and educational programme for training PhDs in technical sciences into the process of research engineers' instruction at NMU. The template curriculum has been developed with due regard to the holistic education paradigm and the synthesis of professional, social and worldview competences. PhD training is based on scientific and educational programme intended to build up integral, general and professional competences of young scholars. The syllabus for the course "Philosophy of Science and Fundamentals of Professional Ethics" has been compiled as a worldview foundation for shaping the mind of a scholar in technical sciences according to the topical issues of co-evolutionary development.

**Keywords:** Doctor of philosophy in technical sciences · Holistic education
Coevolution · Scientific and educational programme
General and professional competences · Philosophy of Science

## 1 Context

Before 2016, post-graduate education in Ukraine was regulated by the standards of the Soviet period. The Law on Higher Education of 2015 established three levels of higher education in Ukraine following the European framework of qualifications: Bachelor, Master and PhD. As of today, the level of PhD has been represented in Ukraine by the degree of the Candidate of Sciences that is essentially different from the PhD degree. The previously accepted system of post-graduate studies had serious drawbacks:

1. Post-graduate programme lasted 3 years. During this period, PhD students were required to publish the results of their research and to defend a dissertation, which is insufficient for all-round accomplishment of a scholar and completion of a cutting-edge scientific research.
2. In the process of studying, a postgraduate did not acquire necessary training in methodological, organizational and worldview domains. 90% of postgraduate study time was allocated for writing a dissertation, which resulted in significant deterioration of its quality, since there was no adequate preparatory training. The former


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postgraduate training pattern did not include practical component, which affected pragmatic aspects of postgraduate research and limited the career trajectory of a scholar after the dissertation defense.

3. Before 2016, postgraduate programmes were not based on the competence approach, which significantly hampered the career growth of prospective scholars in terms of wide range of science socio-cultural integration.
4. The worldview approach to post-graduate training was based on the Soviet tradition of science ideologization, which manifested itself in teaching the course of “Philosophy” mostly in the narrow materialistic framework. Such approach was counteractive to broad-minded attitudes and prospective thinking of a scholar. Thus, the situation called forth cardinal changes in training modern PhDs in our country. In view of the absence of standards for training PhDs in Ukraine, there arises a need to develop standards and curriculum for educating specialists of this level in accordance with requirements of the modern European science.

## 2 Purpose or Goal

The purpose of the research is to substantiate the standard for training PhDs on the basis of the case study conducted at the National Mining University (NMU). The tasks of the research are: to present the general concept of training PhDs, to define the key professional, social, personal and creative competences required for this level, to showcase the ultimate design of scientific and educational programme and curriculum for training PhDs at NMU. We also aimed to introduce the syllabus for the course “Philosophy of Science and Fundamentals of Professional Ethics” as a worldview foundation for scientific research in engineering domain.

## 3 Approach

The present research is based on the paradigm of holistic education, which is understood as synthesis of the scholar personality development in the form of a unity of professional, social, and worldview competences. The latter play the key role in substantiating the scientific and educational programme for training PhDs in technical sciences, because they are instrumental in setting evolutionary goals and formulating innovative approaches in science.

In order to implement the system of PhD training described above, we have used the inter-disciplinary and competence approaches.

## 4 Substantiating of PhD Competences in Technical Sciences

One of the fundamental tasks of science is to qualitatively change the forms of human life. The scientist of the XXI century is becoming more and more responsible for the consequences of transformations brought about not only in material, technical and social spheres, but also in the environment and the surrounding world as a whole. The world is predominantly viewed as an entity, while the man and his socio-cultural space is organically embedded in its holistic picture. Hence, it is necessary that scientific research involve not only professional discovery but also conscious approaches to understanding evolutionary prospects of man and society development. The essence and character of scientific activity are determined by the ability to consciously set goals, which is based on the value and moral orientation of a scholar, understanding of their own possibilities, aims, tasks and responsibility for the transformative activity. Thus, a new scientific and educational programme for training PhDs in technical sciences is aimed at ensuring successful activity of a scientist in line with all world-view, organizational and professional imperatives of our time. In view of the above, we have compiled a significantly revised curriculum for training PhDs in technical sciences at NMU on the principle of complementarity of general and professional competences. Accordingly, the main task of training PhDs in technical domain is to form an integral competence on the basis of interdisciplinary approach to the study programme on the whole. Integral competence of PhDs in technical sciences implies ability to conduct innovative research resulting in creation of new holistic knowledge in keeping with co-evolutionary processes related to man, nature and society.

### 4.1 General PhD Competences in Technical Sciences

Integral competence is a basis for building up general competences of a Doctor of Philosophy which are universal for all areas of study and specializations:

- interactive communication with broad scientific community and researchers in scientific and professional spheres;
- starting up innovative complex projects, ensuring leadership and ultimate autonomy during their implementation;
- social responsibility for the results of making strategic decisions;
- self-development and self-improvement, responsibility for teaching other people;
- generating new ideas;
- mastering scientific methodology;
- mastering pedagogical methodology;
- presentation and discussion of scientific results in a foreign language according to specifics of the study area in oral and written form;
- full comprehension of foreign scientific texts in the field of specialty;
- formation of a systemic scientific worldview;
- development of professional ethics and general cultural erudition.

Considering the competences listed above, we can conclude that in the result of training, a prospective Doctor of Philosophy should possess scientific, methodological, philological, presentational, communicative, ethical abilities, which are based on the systemic scientific worldview and high level of analytical and abstract thinking. It is interdisciplinary approach to the development of general competences that contributes to the formation of a mature mind of a scholar striving for evolutionary prospects of science. It should be noted that general competences are the fundamental basis for training PhDs in technical sciences at NMU which comprise the essence of scientists' education.

## 5 Professional PhD Competences in Technical Sciences

Professional PhD competences derived from general competences are differentiated according to the kinds of professional activity: research, innovation, project design. Let us consider professional competences for the scientific and educational doctorate programme in "Engineering Mechanics".

**Professional competences in research:**

- mastering terminology of applied mechanics;
- learning the history of development and present state of scientific knowledge in specialty;
- learning principal conceptions of applied mechanics;
- understanding theoretical and practical problems of applied mechanics;
- learning conceptual and methodological knowledge in improving technological processes of manufacturing machines and equipment, scientific research and professional activity on the borderline of different areas;
- conducting own scientific research yielding the results characterized by scientific originality in theory and practice;
- solving complex problems in the field of applied mechanics
- applying modern information technologies in scientific and pedagogical activity.

**Professional competences in innovative activity:**

- implementing critical analysis, assessment and synthesis of new and complicated ideas in development of technological processes related to manufacture of machines and equipment;
- solving complex problems in the field of innovative activity;
- skills of registering intellectual property rights;

**Professional competences in project design:**

- presenting ideas for financing scientific research;
- development and realization of the projects, including one's own research, which allow to revise the existing knowledge and create new holistic knowledge, as well as professional practice in the field of developing technological processes related to manufacture of machines and equipment;
- management of scientific projects.

## 6 The Curriculum of the Scientific-Educational Programme for Training PhDs in Technical Sciences at NMU

The curriculum of the scientific-educational programme for training PhDs in technical sciences at NMU based on the competences described above is intended to last 4 years (not 3 years as before). The scientific-educational programme comprises 40 credits, of which 27 credits constitute the compulsory part common for all the doctorate students of the university, and 13 credits go for the variant part, which is determined by the specialty specifics and the free choice of PhDs. Table 1 presents the curriculum of the scientific-educational programme for training PhDs in technical sciences at NMU.

**Table 1.** The curriculum for training PhDs in technical sciences at NMU.

| Kind of educational activity | Credits |
|---|---|
| **I. Cycle of general training** | **27** |
| **Cycle of humanities (university)** | **13** |
| Philosophy of science and fundamentals of scientific ethics | 5 |
| Foreign language for professional purposes | 5 |
| Psychology of scientific research | 3 |
| **Cycle of general scientific disciplines (faculty)** | **6** |
| Mathematical modeling utilizing computer technology in research | 3 |
| Inventing and registering intellectual property rights, evaluating economic efficiency of innovative developments | 3 |
| **Practical training** | **8** |
| Skills of effective presentations | 2 |
| Scientific self-management | 2 |
| Preparation of scientific articles, abstracts, conference and scientific seminars reports | 2 |
| Teaching practice | 2 |
| **II. Cycle of professional training (department)** | **13** |
| **Compulsory part** | **3** |
| Scientific and innovative tasks and problems of the applied mechanics | 3 |
| **Variant part** | **10** |
| **Disciplines of the student free choice (block 1)** | **10** |
| Forming algorithms for statistical control of quality in machine building | 5 |
| Trends in development of computer methods related to optimization of technological processes in machine building | 5 |
| **Disciplines of the student free choice (block 2)** | |
| Tasks and problems of using virtual research devices on the basis of geometric programming | 5 |
| Modern methods of technological processes optimization | 5 |
| **Disciplines of the student free choice (block 3)** | |
| New approaches to studying wear and durability of cutting tools | 5 |
| New approaches in cutting processes research | 5 |
| **Qualification thesis completion** | |
| **Total:** | 40 |

Lists of disciplines in different blocks of the curriculum are compiled by various structural units of the university. Thus, humanities of the general training cycle are the same for all the specialties of the university, while the cycle of general scientific disciplines is designed by the faculty. According to the curriculum, the disciplines of the compulsory and variant blocks of the professional training part are suggested by the related department.

The syllabus for the course "Philosophy of Science and Fundamentals of Professional Ethics" has been developed within the frames of scientific and educational programme for training PhDs in technical sciences by Philosophy and Pedagogy Department of the National Mining University. The objective of this discipline is to form holistic ideas about the role of science and a scientist in society development, as well as about the history and prospects of science development in evolutionary civilization processes. This discipline is compulsory for all the specialties and functions as a worldview and methodological basis for forming the mind of the future scientists.

## 7 Conclusions

Development and implementation of the standards for training PhDs in technical sciences on the basis of holistic educational paradigm will allow to optimize preparation of research engineers in the context of integral formation of professional, social and worldview competences, which contributes to the enhancement of axiological component of engineering and its evolutional socialization.

Reasons focus on competence approach in education:

- trends in integration and globalization of the world economy;
- the need to harmonize the architecture of the European higher education system under the Bologna process;
- the paradigm shift of higher education: from paradigm of knowledge to paradigm of competency - abilities successfully realized in modern society
- in this regard, the transition to 4-year training provides an opportunity to master fundamental and special disciplines (the first two years) and successfully carry out scientific research (the third and fourth year), as practical realization of the competences of the scientist.

Qualitative content and organization changes in designing scientific and educational programme for training PhDs in technical sciences, which aims at building up integral, general and professional competences of a researcher, have laid the basis for the Ministry of Education and Science of Ukraine standard of PhD training, which contributes to integration of Ukrainian science into European space.

# Involving Students in Research with Elements of Game-Based Learning for Engineering Education

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**Abstract.** This work describes the experience of Tomsk Polytechnic University in involving students in scientific research. The involvement is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions. The experience described should be considered a success, as over the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree has multiplied. The competition for enrolling into postgraduate studies has increased as well.

**Keywords:** Game-based learning · Laboratory practicum · Active learning Scientific research activities · Team training · Engineering education

## 1 Introduction

Tomsk Polytechnic University (TPU) is ranking fourth domestically and is the oldest institute of technology in the Asian part of Russia. In the last decade, the university has set a goal to get high rankings in the top part of major international ratings. The development of a research university is implausible without involving students into scientific research, starting from their junior years.

The research work this annotation is a part of describes the university's experience in involving junior grade students in scientific research. The above goal is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions.

The experience described should be considered a success, as in the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree (and then do postgraduate studies) has multiplied.


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## 2 Background

Tomsk Polytechnic University was founded in 1896 as an institute for training practicing engineers. From the very onset, TPU has become the heart of engineering and technical creativity in the Russia's Asian part. From the very beginning of its history, the institute has conducted scientific research within the frame of professional training, and, of course, the students were involved as well. In engineering sciences, the demarcation line between scientific research and engineering development is very thin, if sometimes noticeable at all.

That is why serious scientific research projects have been developed in engineering student project groups (created under the auspices of the respective institute departments as early as in the beginning of the 20th century). In 1953 in the radio engineering department's group directed by associate professor V.S. Melikhov, an amateur TV broadcast station was created that has laid foundation for Tomsk TV broadcast station, the fifth of a kind in the USSR. In all of the above cases, engineering design development was preceded by deep scientific research [1, 2].

Still, despite all these (and other) success stories, the cultivation of student-driven scientific research through science groups is obviously not enough to position the university as a major research center.

## 3 "Training Through Collaboration", a Pedagogical Technology for Game-Based Learning

The theoretical foundation for this technology was laid by American teacher John Dewey, 1916. In Russian pedagogy science, "training through collaboration" has acquired widespread acceptance, thanks to the works by Ye. S. Polat [3].

According to Ye. S. Polat, "training through collaboration", as different from the traditional forms of group work, is peculiar for the following aspects:

1. Mutual dependence of all group members
2. Personal responsibility of each group member both for their own success and for the success of other fellow members
3. Joint educational, cognitive, creative and other activities of students in a group
4. Student activity socialization in groups
5. Overall group activities are evaluated by adding up the results of assessing students' form of group communication as well as their academic achievements.

The implementation of education through collaboration is underpinned by a common system. The teacher selects students to form a group. Each group should be formed to include students with a varying level of command of the foreign language, different experience of collaborative educational efforts, the group should be a mix of genders, etc. Such principles of selection give each team member a real opportunity to develop the necessary skills in the course of collaborative project delivery. Also, it is obvious that there a different skill set will be developed by each member. For students lacking in linguistic proficiency, that would be language communication skills. For students with high linguistic proficiency, the skills acquired previously will develop, as well as leadership skills, the ability to organize team education, etc.

1. Each group is given a problem that requires each member to participate in the solution. Roles are allocated between group members, and each is provided with a separate work cluster.
2. Each group is given a set of required materials (one text copy, one set of exercises, one web page to keep track of the project, etc.).
3. One mark is given to the whole group for the project delivery [4].

The peculiarity of the “education through collaboration” pedagogical technology is that each participant is responsible both for their part of the job and for the entire project. Eventually, it is not the work of every single team member that gets evaluated. It is the result of the collaborative effort. The final product will tell how the students managed to collaborate. This teaching technology encourages communication and teamwork to achieve the best result.

The general experience of project work shows that education through collaboration as a pedagogical technology for game-based learning may become efficient for groups of 4–5 persons with varying level of competence. It can be presented as a part of blended learning [5]. While working together on the project, the participants are inherently placed into a situation when the project can be delivered, and positive results can be achieved through collaboration only. In the meantime, in the course of project delivery, the team decides which member is capable of leadership and who is apt for research activities and who is more comfortable as a doer.

## 4 Possible Solutions to the Problem

The first step to solve this problem was the introduction of scientific research elements into the laboratory practicum, utilizing the “training through collaboration” technology as game-based learning. Laboratory practicum is an integral part of engineering and natural science courses and is a required activity for all students without exception. Traditionally, a student group is broken into teams, three to five persons each. Each team’s program is compiled in such a way, so that it’s impossible to complete it without role allocation and personal responsibility of each student for their respective part of the common effort. Such workflow is applied for all laboratory practicums, irrespective of the university department. Role allocation is done by team members, and the teacher is not getting involved in any way. However, the teacher takes notes which roles which students take. Later on, this information is useful for outlining the student’s education path and deciding whether to offer the student to participate in real scientific research, send the student to work at an industrial plant or in a scientific laboratory or recommend them to pursue Master's or Specialist's degree, or to graduate with Bachelor's. Of course, role allocation alone is not enough to draw conclusions about aptitudes and capabilities. Still, when putting together a student's profile, this information may come handy.

Starting with the second grade already, students are taught to correctly set up experiments and are required to substantiate their choice of the physical model of the researched process/phenomenon as well as the experimental toolset. It is also important to teach students how to process experimental results. At the department of experimental physics and general physics, this is taught as early as the 1st semester of the Bachelor's course [6]. Since teaching physical and technical subjects is the current work authors' specialty, the examples are taken from the departments of the respective profiles. The result of this training is the convincement of a student that any natural science experiment is an event with certain probability, so the result thereof must be treated accordingly. Further on, when experiments are set up and conducted in the course of other laboratory courses and educational and scientific research efforts are carried out, the students do not feel repulsion or have difficulties doing multiple repeat measurements (i.e. collecting statistical material) and further statistical treatment of the experimental results.

Starting from the first grade of Bachelor program, scientific research elements are included into the laboratory works curricula. For example, for the work "Determining the free fall acceleration", the department of experimental physics suggests that students not only determine the acceleration but also calculate the dependency between the free fall acceleration and the latitude, taking into account the Coriolis force and the altitude above sea level. The department of electric networks and electric engineering suggests that when performing the laboratory work "Emission of a two terminal circuit", the dependency of the output parameters of the circuit on the load intensity and type as well as internal impedance of the circuit should be researched. Also, the conditions for matching an active two terminal circuit with the load are to be determined.

Correctly documenting the research results is another important aspect. That is why specific attention is paid to adequately composing laboratory work results. Students might think those are just teachers' critiques but we need students to achieve understanding that a research result only matters when it is has been made publicly available to scientists. Therefore, the publication must be easily readable and comply with the academic standards.

Senior grade Bachelor students get access to experimental facilities and installations that were used (or are used) for real scientific research. This way, the department of high voltage electricity physics and high current electronics uses the installation described in [7] (see Fig. 1). A research of the characteristics of contaminated insulation of overhead power transmission lines (a real-life scientific research) was performed on that installation.

**Fig. 1.** Insulator testing unit

At the Physical and technical institute, a series of laboratory courses have been developed for the operational scientific nuclear reactor IRT-T (see Figs. 2 and 3), that is actively used for scientific research and isotope production. Now it is also used in the students' laboratory courses.

The next step is introducing discipline named "Educational and research work for students" into the curriculum of virtually all engineering specializations. This discipline is taught starting the second grade of Bachelor's degree course. Within the scope of this discipline, sets of lectures are delivered to students: bibliographic search, theory of inventive problem solving, rules and techniques for preparing research publications, etc. This is very useful for a future researcher: student will already be able to properly handle experimental equipment, thanks to laboratory practical trainings on chemistry, physics, theoretical and applied mechanics and electrical engineering. Then, with the

**Fig. 2.** A group of students at the IRT-T reactor

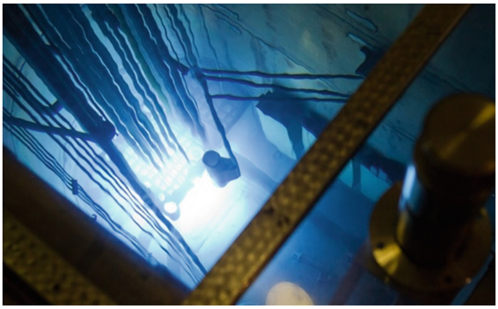

**Fig. 3.** Reactor's active zone

assistance from their mentors, the students will gain the expertise and skills that they lack in when they start real research work. However, it is equally important to correctly set the research goal, define the approaches to its solution, choose the adequate physical model for setting up the experiment and choose the mathematical model for processing the experimental results. Besides any research result is only worthy if it becomes publicly available.

Starting from the second grade, students work with literary sources pertinent to their specialization and write papers on topics set by their academic advisors. For solving real research objectives, third grade students are assigned to labs. There they participate in experimental research in conditions that are as close to real life as possible, the whole process based on game-based learning used together with "training through collaboration" [8]. By that time, the students will have had enough time to study the research topics and to master experimental research methods. It allows them to become co-authors of articles written by their academic advisors and deliver reports at international science conferences.

Thus, by the moment when a student earns their Bachelor's degree, they will have become a full-featured member of a scientific research team. The student will have a set of science research skills, from setting the goal to adequately interpreting experimental results. Such students' graduation papers are normally based on the results of real scientific research conducted in the laboratory where they have been studying. In most cases, such papers are the starting point of more serious works performed to pursue Master's degree.

For Master's Degree students, scientific research involvement is the cornerstone of their curriculum. Master's Degree students can only pass graduation certification if they have published an article or delivered a report at a science conference. The paper itself is called a dissertation (i.e. "a document submitted in support of candidature for an academic degree or professional qualification presenting the author's research and findings" [9]) for a reason.

## 5 Conclusion

The above efforts have allowed for substantially increasing students' interest and motivation towards scientific research activities. There is a steady annual inflow of graduates (between 900 and 1100 Bachelor degree holders) who choose to continue their education and seek Master's degree. Also, about 200 Master degree holders go for post-graduate. It is also worth noting that in the recent four years, the number of graduates who have chosen science research as their profession is increasing, year to year. As of current, over 80% of Master degree students have received their Bachelor's degree at TPU. You can decide for yourself whether this is good or bad, depending on how you look at it. On one side, when students from outside TPU come to TPU to pursue Master's degree, it is a win because it means TPU's popularity in the education community increases, domestically and internationally. On the other hand, candidates compete to enroll into Master's course (in 2016 the competition was 2.5 contestants per vacancy). So, if more TPU's students succeed, that means they are better prepared.

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## References

1. Mapelli, C., Klochkov, N.S., Egorov, U.P., Zabrodina, I.K.: Tin and nickel influence on the structure and properties of the leaded bronze obtained by means of the centrifugal casting. In: International Conference on Industrial Engineering, vol. 870, pp. 248–252. Solid State Phenomena, May 2016
2. Bychkov, P.N., Solodovnikova, O.V.: Influence of the radiation destruction of polymeric insulation on its ageing in the impulse electric field. Adv. Mater. Res. **880**, 88–92 (2014)
3. Abdrashitova, M.O., Zabrodina, I.K.: Pedagogical conditions of the development of sociocultural skills of students training for theory and practice of translation by means of modern Internet-technologies. In: Proceedings of the 2nd ASSHM, China, vol. 12, pp. 93–96, December 2014
4. Zabrodina, I.K., Richter, S.O., Bogdanova, A.G., Bogdanova, O.V., Lilenko, I.Y.: Experimental learning of foreign language with the socio-cultural skills development method by means of modern internet technologies. Procedia – Soc. Behav. Sci. IECC **215**, 141–146 (2015)
5. Rulevskiy, V.M., et al.: Mathematical model for the power supply system of an autonomous object with an AC power transmission over a cable rope. In: IOP Conference Series: Materials Science and Engineering, vol. 177, No. 1, p. 012073 (2017)
6. Bevington, R., Robinson, D.K.: Data Reduction and Error Analysis for the Physical Sciences, 3rd edn. McGraw-Hill, New York (2003)

7. Bychkov, P.N., Zabrodina, I.K., Shlapak, V.S.: Insulation contamination of overhead transmission lines by extreme service conditions. IEEE Trans. Dielectr. Electr. Insul. **23**(1), 288–293 (2016)
8. Isaev, Y.N., et al.: Parameters assessment of the inductively-coupled circuit for wireless power transfer. In: IOP Conference Series: Materials Science and Engineering, vol. 177, No. 1, p. 012097 (2017)
9. International Standard ISO 7144: Documentation – Presentation of theses and similar documents, International Organization for Standardization, Geneva (1986)

# The Issues of Teaching English and German for Specific Purposes to the Academic Staff of a Technical University

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**Abstract.** Due to internationalization of higher education foreign language communicative competence of the university staff is beginning to be viewed as an integral component of their professional competence. The paper discusses the experience of National Research Tomsk Polytechnic University (TPU) in implementing Foreign Language for Specific Purposes (LSP) courses for the academic staff as a part of their professional development training in English and in German. The aim of the paper is to introduce a model of LSP courses appropriate for the TPU faculty and staff.

**Keywords:** Foreign Languages for Specific Purposes (LSP)
Professional development training

## 1 Context

The paper discusses the experience of National Research Tomsk Polytechnic University (TPU) in implementing Foreign Language for Specific Purposes (LSP) courses for the academic staff as a part of their professional development training in English and in German. The needs for the TPU academic staff to increase the level of foreign language proficiency are recognized by the University management and underpinned in the TPU Programme for Promoting its competitiveness (the so-called Roadmap) for 2013–2020 [1]. According to this Programme, TPU aims at building strategic partnership and networking cooperation with foreign partners, at positioning as an international platform on formation and development of resource-efficiency ideas, at building internationally oriented university infrastructure, etc. [1]. Language proficiency of TPU faculty and staff is supposed to be one of the mechanisms of reaching these aims. Therefore, foreign language certification has been included into the list of the staff key performance indicators within the effective fixed-term contract system and, furthermore, into the list of additional qualification requirements considered in the employment process.

The priority in the Programme is given to English as a dominant language in international cooperation of today. However, acquiring the specialized linguistic competence in German can also be considered essential since Germany is one of the longstanding partners of TPU in education and research (http://portal.tpu.ru/ciap/partners/germany). In these circumstances the implementation of LSP programmes both in English and in German seems to be justified.


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## 2 Purpose

Taking into account the development priorities of TPU as a national research university, language proficiency of its faculty and staff can be viewed as an effective tool for the university integration into the global educational space; besides, as a good marketing tool helpful to enhance its competitiveness among other Russian universities. The objectives that are to be pursued in this case should cover all spheres of the university life – educational, research and administrative:

- teaching special disciplines in a foreign language both to the domestic and foreign students;
- advancing TPU research in the global scientific community;
- building strategic partnership with foreign universities and organizations, etc.

Hence there is a need to design an efficient and functional model of the LSP courses with the focus on these large-scale tasks as well as on the specified needs of the individual learners. The latter requirement poses a major difficulty since the language abilities and previous language learning experience of this category of adult learners may vary significantly. Besides, the learners' professional expertise can be rather diverse: being the academic staff of one university, they are specialists in different technical fields such as chemical engineering, petroleum engineering, power engineering, metallurgy, biotechnology, robotics, information technology, mathematics, physics, and so on.

Additionally, the programme developers are challenged by the fact that training should be realized through the in-service mode which means that the TPU teachers, researches, and engineers have to combine learning a foreign language with their daily professional duties. In the situation when great emphasis is put on the definite practical outcomes of language learning within a relatively short period of time (the duration of a singular professional development programme is usually one semester) this is not an easy task to achieve. Apparently the proposed model of professional training in a foreign language must go beyond the traditional paradigm.

## 3 Approach

The elaboration of the appropriate model of LSP courses in the conditions outlined requires reviewing the status and current practices of LSP teaching in theory, and most importantly, conducting needs analysis survey among the target learners.

Literature overview shows that the concept of LSP has a number of interpretations. Generally, it can be defined as "language research and instruction that focuses on the specific communicative needs and practices of particular professional or occupational groups" [2, p. 391]. LSP courses are usually applied to English. "Anglophony" has become the communication norm in a variety of professional fields throughout the world [3], yet there can be any target language that is needed by the learners for their specific purposes. Modern researchers claim that "the monolingual dominance of English needs to be rethought" [4], and the importance of foreign language proficiency for the modern professionals working globally should not be confined to learning English only [5, 6]. Taking into account these considerations, the idea of parallel LSP training both in English and in German for the TPU academics seems to be flexible and well-balanced.

In scholarly circles LSP is sometimes subdivided into language for academic purposes (LAP) and language for occupational purposes (LOP). In practice though, it is not always possible to draw the distinct difference between the two variations. Obviously, in TPU where the special category of adult learners need foreign language skills for their research as well as for daily job performance both these aspects are relevant and should be reflected in the programme.

The attempts to trace the LSP research tradition and practice in Russia [7–10] have revealed that in Russian context the concept of LSP is relatively new. Nonetheless, language politics here is undergoing profound changes and the concept of foreign language for general purposes (LGP) is beginning to be complemented by LSP. The status of LSP is gradually increasing and there appears an impetus for the introduction of LSP courses into the university settings – not only for the students but also for the academic staff.

Researchers agree that preliminary needs analysis survey is essential for the LSP programme design [4, 6]. In this study, a present situation analysis has been conducted in order to identify the linguistic preferences of the academic staff of TPU. To investigate the preferences and needs, data were collected through a questionnaire which contained questions about the potentially interesting topics and desirable language skills (each participant could choose several alternatives or provide their own answers).

Needs analysis survey has revealed a number of potentially important aspects of LSP courses in English and in German for the TPU staff:

- foreign language for engineering;
- for teaching special disciplines (foreign language as a medium of instruction);
- for reading specialized literature;
- for presentations;
- for writing scientific papers and grant proposals;
- for business communication;
- for passing language certification exams.

Obviously, in this context LSP courses cannot be limited to a set of specific topics (academic and professional) that could be learnt from a singular LSP textbook. It is believed that the solution can be found in the elaboration of a special form of interaction between the LSP teacher and the learners where the teacher adopts the position of a language consultant, facilitator (flexible enough to give individual advice), and the learners, already experts in their fields, become active participants and even contributors to the educational process – self-motivated, capable of working independently at their own learning pace.

## 4 Designing LSP Courses in English and in German for the TPU Academics

The factors that were considered when designing LSP programmes in English and in German for the TPU academics include:

- TPU strategic goals;
- learners' needs, levels and interests;
- in-service mode of professional development training;
- emphasis on practical outcomes within a relatively short period of time.

In this context a modular approach to organize a language curriculum was selected. The advantage of this approach is that it allows to consistently and gradually realize language training at different levels starting from A1 till B2 of the European communicative competences (that corresponds to Modules 1–4 of the professional development programme designed at TPU). Progression from one level (or Module) to another implies the increase in the degree of specialization, i.e. language activities and topics become more complex and professionally oriented.

The current paper focuses on the description of Module 3 of the professional development programmes in English and in German as the authors have the experience in their management and teaching.

The primary *aim* of the LSP programmes at Module 3 is to develop a professional foreign-language competence in the university research and teaching staff that would enable them to solve problems according to their specialization at the level B1 of the European communicative competences.

*Duration:* 18 weeks.

*Total amount of hours, including contact hours and the hours for learners' independent work:* 648 (English); 720 (German).

*Mode of teaching:* in-service mode implying the combination of face-to-face teaching and e-learning (online courses serve as a support platform offering links to the authentic materials in a foreign language and a variety of tasks to be accessed at any time convenient for the learners).

*Course schedule:* 4–6 contact hours per day; 22 contact hours per week.

The participants are selected on a competitive basis or after the successful completion of Module 2 in the corresponding language (English or German).

Table 1 below illustrates the range of disciplines within each programme.

As shown in Table 1 all disciplines in both programmes can be subdivided into two major groups:

- practical disciplines for the development of general language skills and training for the language certification exams;
- specialized disciplines to equip the learners with the foreign language skills needed in their professional career.

At the end of the course (as a form of their final assessment) the learners prepare a graduate research paper in accordance with the requirements of the academic style in the foreign language studied (English or German) and deliver it in the form of an oral presentation before the audience. The specialized topics for the graduate research papers are selected by the learners themselves (these topics should be correlated with the university priority fields of research and development). The teachers of the programme act as language consultants, not as scientific supervisors.

**Table 1.** Disciplines of professional development programmes in English and in German (Module 3).

| Module based programme: German | Module based programme: English |
|---|---|
| Culture of speech communication in German | Modern English in conversation |
| Grammar for professional communication in German | English grammar |
| Training for German certification exam (B-level): speaking (Sprechen) | FCE exam training practice: speaking |
| Training for German certification exam (B-level): reading (Lesen) | Reading comprehension practice |
| Training for German certification exam (B-level): writing (Schreiben) | FCE exam training practice: writing |
| Training for German certification exam (B-level): listening (Hören) | Listening comprehension practice |
| Translation of specialized texts | Writing functional styles |
| German for scientific purposes | English for academic purposes |
| German as a conference language | English for business and professional communication |
| German for business and professional communication | Psycho-pedagogical principles of the educational process in higher education institutions |
| Psycho-pedagogical principles of the educational process in higher education institutions | |

## 5 Outcomes

The outcomes of the proposed LSP model implementation could be represented in the so-called language portfolio, a form of record of the learners' language learning achievements and acquired competencies at levels B1/B2 (Independent User) of the European communicative competences.

For example, the learners after the successful completion of the professional development programme in a foreign language are expected to be able to:

- provide a detailed description of their professional portfolio of a teacher/researcher/engineer at a technical university;
- engage in a dialogue/negotiations with native speakers of English and German on common and professional topics;
- share the results of their research work in the form of oral presentation;
- carry on business and academic correspondence with international partners;
- use the foreign language as a medium of instruction within a specialised field;
- apply for research grants;
- pass a foreign language certification exam.

The above-mentioned elements of a language portfolio can find implementation in the various types of professional activities of TPU academic staff which includes not only the pedagogical activity, but also the research activity, the management activity and can contribute to the realization of the university strategic goals.

Tentative results indicate that the LSP instruction model implemented at TPU is viable and effective: 87–90% of the learners successfully complete the professional enhancement programmes in English and German and acquire the above-mentioned skills and competencies. About 80% of the programmes graduates prove the level of language proficiency passing TPU certification exams.

## 6 Conclusion

TPU has some established traditions in delivering professional development training programmes in foreign languages for its faculty and staff. The proposed model for LSP courses design seems to be valid since it focuses on the current university management goals as well as the learners' needs, takes into account the learners' different language learning and professional backgrounds, implies a set of practical learning outcomes both for academic and professional settings (language portfolio). It may need further development and improvement, though.

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## References

1. Chubik, P.S.: Action plan on the implementation of National Research Tomsk Polytechnic University programme for promoting the competitiveness ("Roadmap") for 2013–2014. Moscow (2013)
2. Hyland, K.: English for specific purposes: some influences and impacts. In: Cummins, J., Davison, C. (eds.) International Handbook of English Language Teaching. Springer, New York (2007)
3. Knapp, K., Seidlhofer, B. (eds.): Handbook of Foreign Language Communication and Learning (2009). Cooperation with Henry Widdowson
4. Kärchner-Ober, R., Hunger, A., Werner, S.: German for specific purposes (GSP) – a pathway to studies in engineering at University of Duisburg-Essen. In: Proceedings of the 43rd SEFI Annual Conference 2015, European Society for Engineering Education (SEFI), Orleans, France (2015)
5. Riemer, M.J.: English and communication skills for the global engineer. Glob. J. Eng. Educ. **6**(1), 91–100 (2002)
6. Martin, E.: Designing and Implementing a French-for-Specific-Purposes (FSP) program: lessons learned from ESP. Glob. Bus. Lang. **5** (2010). Article 3
7. Fofanov, O.B., Sidorenko, T., Zamyatina, O.: Development of professional communicative competence of IT-students through learning foreign language for specific purposes. World Trans. Eng. Technol. Educ. **8**(1), 101–106 (2010)

8. Kazakova, O.: Language for specific purposes: methodological problems, trends and perspectives. Procedia Soc. Behav. Sci. (2015). Worldwide trends in the development of education and academic research. http://www.sciencedirect.com/science/article/pii/S1877042815060425. Accessed May 2017
9. Gunina, N.: Action Research Into Teaching English in Russia's Professional Context. Cambridge Scholars Publishing, Newcastle upon Tyne (2015)
10. Zakharova, E., Bogdanova, A., Zabrodina, I., Komandakova, M., Lilenko, I., Tran Dinh, S.S.: Integrating a technical communication course into the curriculum of students majoring in translation. In: Proceedings of INTED2017 Conference, 6th–8th March 2017, Valencia, Spain, pp. 4538–4541 (2017)

# Professional Technical Teacher Education at CTU in Prague

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**Abstract.** Czech Technical University (CTU in Prague), Masaryk Institute of Advanced Studies (MIAS), Department of pedagogical and psychological studies, prepares students for the profession of technical teacher in the bachelor study programme Specialization in Pedagogy. Thus, the current state of knowledge of Educational Science is applied into specialized areas of technical disciplines. Actually, technical knowledge is a prerequisite for the field of study Technical Teacher Education, and Vocational Teacher Education. A structure and the content of teacher preparation is systematically modernized due to development of humanities and technical sciences.

This paper presents an overview of current activities of the Czech Technical University in Prague, three-year project (2014–2016) Readiness of Technically Educated Students for the Teacher Profession, Management and Motivation as a part of the TQM of under-graduate teacher preparation within the Fund of Educational Policy of Ministry of Education. This indicates the specific of education in the Czech Republic. Technical teacher education is highly relevant from many perspectives nowadays.

**Keywords:** Fund of Educational Policy · Motivation
Professional teacher development

## 1 Introduction

We are aimed to educate the top professionals who will be motivated to become a teacher of technical subjects. Our graduates have not only the knowledge base in engineering, they gain the educational and psychological fundamental skills and competencies that will enable them to cope with the demands of the teaching profession. Professional teacher education is regulated by educational legislation, it reflects the needs of employment of graduates of technical and higher education as well as practical education, in qualified positions.

MIAS, CTU in Prague launched a three-year project (2014–2016) Readiness of Technically Educated Students for the Teacher Profession, Management and Motivation as a part of the TQM of undergraduate teacher preparation within the Fund of Educational Policy of Ministry of Education. The aim was to support projects through public higher education study programs focused on pedagogy and teacher training and,


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in general, to improve the quality of higher education teaching staff. Another objective was to decrease fluctuation of graduates from teaching programs, to prevent them to leave the education sector and moreover to promote their motivation to take up employment as teaching staff at different levels of educational institutions. The call was so focused on supporting the development of professional readiness of students of teaching programmes with purpose to facilitate their entry into school practice.

What competencies teachers should meet? Teachers should acquire knowledge base, which consists of several areas: branch component (technical education), didactic component, pedagogical-psychological component, generally cultivating component (a university-wide basis) and teaching practice. In accordance with the findings of educational research in teacher education, we place increasing emphasis on competency model of teacher preparation, which allows our graduates to create an autonomous strategy of educational work. Different methods are applied within the didactic component of professional teacher preparation, such as case studies, as well as analysis of different educational outcomes as well as pedagogical presentation. These methods help students reflect the educational process in its complexity.

The teacher should be proactive, communicative, creative, independent, active, critical thinking, innovative, stress resistant, able to build and maintain the authority, open to change, empathetic towards pupils, parents and colleagues, willing to continuous learning, enthusiastic, moral, exemplary, assertive, self-reflective, flexible, teambuilding … thanks to all these competencies and broader framework exceeding of the technical education graduates of professional teacher education can find a job outside the teaching profession as well. With regard to the demands of the present knowledge and learning society, a greater emphasis on language skills (1–2 languages), soft skills, digital literacy, incl. mastering smart technologies is placed.

## 2 Approach

Besides conventional lectures and seminars, teacher presentations as another very important form of professional teacher preparation are widely used. Pedagogical presentations integrate knowledge, skills and ability to convey technical subject to specific students, or pupils at college or vocational school.

How should I prepare for class? What should I teach my students? How to achieve this? How do I evaluate? Through what assignments and tasks? By means of what teaching methods? These are just some of the questions that are addressed during the course of Teaching Methodology where all components (besides didactic one) of professional teacher preparation should be integrated.

Case studies, videos, sample lessons and any other activities are used to promote motivation of students in terms of didactic analysis of the educational process in technical subject. An important, significant component of teacher training are workshops, whose main purpose is to prepare students for teaching practice, the opportunity to undergo the experience of "my own class in rough" as an active method.

Didactic analysis provides many interesting ideas and inspiration for further improvement. Students compare their preparations on the one side and pedagogical performance of their own on the other side, they reflect themselves, how do they perceive the reality, what they succeeded, what they failed, including explanation why do they evaluate their pedagogical performance as follows.

Besides the immediate face-to-face feedback, students have the opportunity to get their records of pedagogical presentations, incl. audio track of all evaluators who participated in the discussion. These activities were involved as a part of the Fund of Educational Policy of Ministry of Education, where we collaborated together with colleagues from partner universities and experts from different areas of teaching practice.

### 2.1 Teaching Practice

For CTU MIAS it is very important to cooperate with contracting secondary industrial schools, secondary vocational schools and vocational schools. In these schools, under the professional supervision of a faculty teacher, pedagogical practice during which students get a real idea of how the school works is realized.

Students will be introduced during the pedagogical practice by the means of hospitality, seminars with experienced teachers and observation with the school as a whole, its atmosphere, social relations, the school and teaching climate, the way of management, the role of students and teachers and their mutual interaction and communication.

Collaboration with quality secondary vocational schools is a guarantee of the quality of the guidance of applicants for the pedagogical profession of a teacher in vocational education.

Contemporary pedagogical practice according to the school's conditions includes a number of practical activities in the broader sense, such as participation in the teaching council, class meeting, meeting of the subject committee or realization of excursion.

Students will be acquainted with their field of study in the field of teaching and non-teaching activities of pedagogical staff, with the issue of educational counseling, with the activities of the school psychologist, the prevention methodology and with the duties of the class teacher (class lessons, classroom self-management, etc.). They will also familiarize themselves with the creation and implementation of the school educational program, with project documentation for teaching the subject, the field (educational programs, curricula, thematic plans, etc.) and related documentation (class books, etc.).

In addition to its own pedagogical activities, the Department of Pedagogical and Psychological Studies (MIAS, CTU in Prague) also deals with scientific and research activities so that we have the "own source" of enriching and improving the pedagogical process. In the last year, two scientific monographs have also been published, which represent, for our students, a valuable source of the latest pedagogical knowledge.

## 3 Outcomes

Over the last three years we have implemented several educational activities within the Fund of Educational Policy of Ministry of Education, which enrich the curriculum (invited lectures, workshops, shadowing, focus groups, etc. Relevant outcomes will be presented to the conference audience.

Structured interviews with students of 3rd year confirmed that this is a very effective way to gain insight on how they can teach more effectively, how to develop pupils' creativity, how to convey technical knowledge in view of pedagogical, psychological and didactical aspects. Students generally appreciate the possibility of immediate feedback from their classmates, as well as from our teachers.

### 3.1 Some Examples

Students (3rd year/grade of study in the field of Teaching Practical Teaching and Vocational Training) commented on the evaluation of the study program. Students positively expressed their opinion on the didactic analysis of the subject. The possibility to watch yourself through videotapes and discuss together with the teacher the achievement of learning goals. It is desirable to focus on the field of psychology in the discussions and to make a video as an example of the proper realization of the lesson.

The most interesting subjects from their point of view were sociology, psychology and ethics and, as a very beneficial one, the students consider rhetoric at the beginning of the study. Students recommend a practical seminar focused on LMS Moodle.

Motivation to study was encouraged by shading and interesting workshops. The opportunity to compare own lessons with colleague´s lessons and let yourself inspired.

In the lectures, students appreciated the focus on practice and practical demonstrations. Students recommend continuing of these lectures and invite experts from pedagogy and psychology and realize team teaching. Socio-pathological phenomena, social psychological counseling and digital competences were the most beneficial and motivating lectures for students for their further study.

A positive shift in their future practice (from the beginning of the project in 2014) is perceived by all of the students. They include, for example:

"Another way how I can learn and improve my subject".

"I learned how to transform the curriculum into transferring knowledge to pupils."

"I am able to apply in lessons how to develop pupils' creativity".

"We could quickly realize and verify what can and can not be realized through this path."

"I realized the importance of social ties with organizational forms and teaching methods."

At the end of the panel discussion, students responded to a question about the topic they most preferred. This work deals with didactic technology and new technologies. More specifically, the application of digital technologies to the educational process. Have electronic learning support from this area and create backgrounds and methodological sheets for their lessons.

### 3.2 Questionnaire Survey

Among the students of the specialization program in pedagogy were distributed questionnaires aimed at providing feedback on the project results (Tables 1, 2 and 3).

Questionnaire survey was participated by a total of 46 respondents (Graph 1).

**Table 1.** Questionnaire survey (source: the authors)

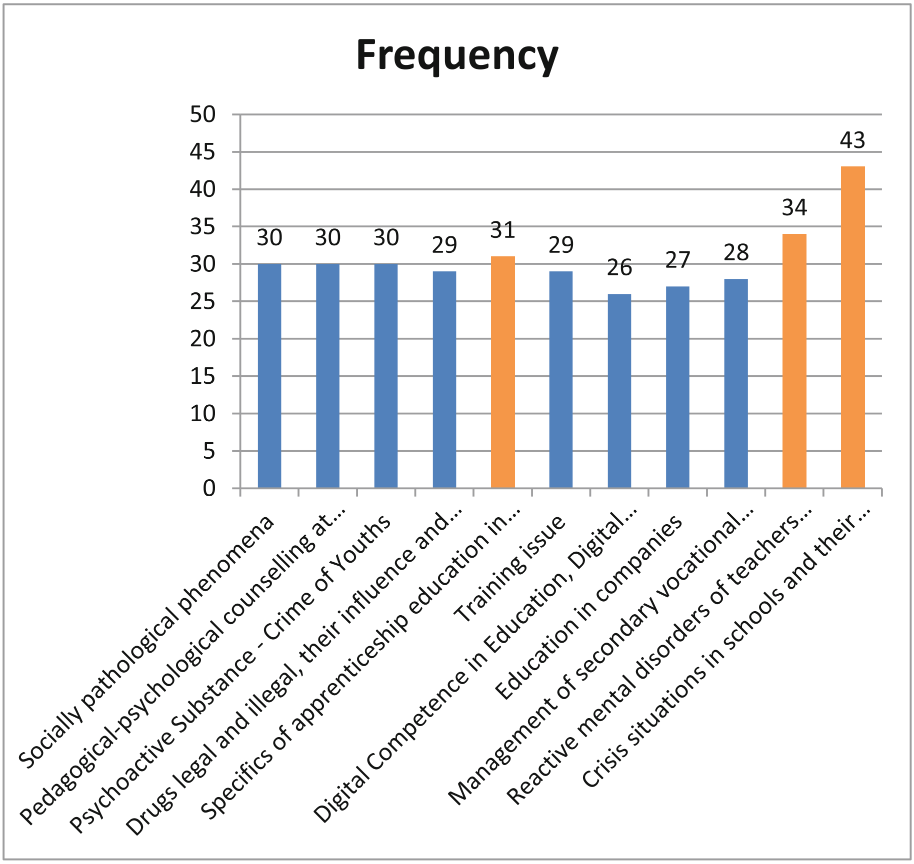
| Class | Field of study (quantity) |
|---|---|
| Teaching of vocational subjects | 16 |
| Teaching of practical teaching and vocational training | 30 |
| Total amount | 46 |

**Table 2.** The contribution of lectures (source: the authors)

| Name | The contribution of lectures |
|---|---|
| Definitely yes | 23 |
| Rather yes | 23 |
| Rather not | 0 |
| Definitely not | 0 |
| I do not know | 0 |
| Total amount | 46 |

**Table 3.** Attendance of individual topics (source: the authors)

| Attendance of individual topics | Frequency |
|---|---|
| Socially pathological phenomena | 30 |
| Pedagogical-psychological counselling at secondary schools (case studies) | 30 |
| Psychoactive substance - crime of youths | 30 |
| Drugs legal and illegal, their influence and method of diagnosis | 29 |
| Specifics of apprenticeship education in the Czech Republic | 31 |
| Training issue | 29 |
| Digital competence in education, digital education strategy 2020 | 26 |
| Education in companies | 27 |
| Management of secondary vocational school | 28 |
| Reactive mental disorders of teachers related to the demands of the teaching profession, the risk of using hypnotics, sedatives and other psychoactive substances, possible use of safe medication | 34 |
| Crisis situations in schools and their solutions | 43 |
| Total | 337 |




**Graph 1.** Frequency (source: the authors)

From the attendance point of view (number of participants), the following places were placed in the first places:

1. Crisis situations in schools and their solutions.
2. Reactive mental disorders of teachers related to the demands of the teaching profession, the risk of using hypnotics, sedatives and other psychoactive substances, possible use of safe medication.
3. Specifics of apprenticeship education in the Czech Republic (Table 4).

**Table 4.** Top rated topics (source: the authors)

| Top rated topics | Frequency |
|---|---|
| Crisis situations in schools and their solutions | 15 |
| Reactive mental disorders of teachers related to the demands of the teaching profession, the risk of using hypnotics, sedatives and other psychoactive substances, possible use of safe medication | 10 |
| Training issue | 6 |
| Digital competence in education, digital education strategy 2020 | 4 |
| Legal and illegal drugs, their influence and method of diagnosis | 3 |
| Specifics of apprenticeship education in the Czech Republic | 2 |
| Management of secondary vocational school | 2 |
| Pedagogical-psychological counselling at secondary schools (case studies) | 1 |
| Psychoactive substance - crime of youths | 1 |
| Education in companies | 1 |
| Total amount | 45 |

Respondents positively evaluated the contribution of lectures, the possibility of confronting the theory with the practice, the attractiveness of the topics offered, the possibility to discuss with the leading experts, their commitment and, above all, the portability of these outcomes into practical life. Many students, in their responses, stated that these are topics that they perceive as highly relevant for the teaching profession. The fact that less traditional topics (especially crisis situations in schools and their solutions) have been enriched by foreign experience of invited experts is also of no less importance. According to the view of the respondents importance of the health and safety of pupils as well as of the teachers was also not neglected. This value and its importance are perceived by students as very important, referring to the need to be prepared for emergencies and to know how to survive the attack.

We were also wondering what other topics the students would welcome. Respondents mostly mentioned topics such as work with gifted pupils, specific learning disabilities, motivation in general, or burnout and prevention syndrome, as well as prevention. It should be added that most of these topics are, to the extent necessary, part of compulsory education in selected subjects.

Some students perceived positively the open approach. During the workshops, they were able to discuss openly the negative aspects associated with the educational process with the participation of a counsellor. In general, the possibility of confronting the theory with practice - examples from practice, the use of theoretical knowledge in the practice of schools (a total of 39 records out of a total of 45 respondents - note: 1 respondent did not participate in the workshop) was the most frequently appreciated. Secondly, in terms of frequency of responses, the contribution to pedagogical theory (35 entries), then third was importance for the teacher's profession (33 entries).

In the case of shading, the most frequently mentioned answer was, as in the case of workshops, the need to confront the theory with the practice, which was clearly fulfilled, this option was selected by 7 respondents from the 11 students who participated in the shading.

### 3.3 Structured (Controlled) Interviews

Within the framework of the project Fund of Educational Policy of Ministry of Education, controlled interviews were conducted with the teachers of the selected contracting secondary school, in which workshops were held, respectively shading. The school where the most workshops and shading took place was selected, the Secondary Technical School of Building and Gardening in Prague, Jarov. For the controlled interviews, a total of 6 teachers, including faculty teacher, who were willing to participate in this managed interview in their free time, were selected in cooperation with the faculty teacher of this school. In the first part of the interview, questions were raised at the beginning on more general topics related to the teacher's profession. The second part of the structured interviews was more focused on the experience of the implemented activities throughout the project.

Teachers perceive:

- Teachers are currently very intensely and positively perceived to have great support for craft and its and popularization.
- In this particular school, teachers feel positive about the support from the municipality, which they very often personally relate in their fields in the form of various projects, support for students 'and teachers' excursions abroad even for apprenticeships Support and promoting crafts in the media results in increasing the prestige of teachers. A number of teachers from this school reported that they have been filming various programs for Czech Television several times and they like to enjoy the results in their privacy as well. All this contributes to the feeling of prestige, the well-done work and the sense of the craft.
- Positive perceptions of the interest of students in their fields of study and the increasing number of students in this school.
- They greatly appreciate the excellent equipment of the machines and aids so that pupils and teachers work and learn the most modern machines and tools that exist for the given field.
- In this particular case, the strong side is the certainty resulting from the stability of the institution. The above-mentioned secondary school is already an established workplace with built-up prestige and is not so strongly threatened by population fluctuations or other risks of new established schools or accredited disciplines.

The second specialized part of the interviews was focused on the evaluation of the contemporary cooperation in the provision of pedagogical practices or other forms and possibilities of future cooperation between secondary school and CTU MIAS.

After evaluating the second specialized part of the interviews, the following strengths and weaknesses can be highlighted based on teachers' responses:

- Teachers who begin or have short-term experience, about 5 years, have a very positive assessment of pedagogical practice and the opportunity to see how other experienced teachers do it and try out teaching in other classes or schools, including own feedback in the form of an analysis of their teaching.
- The voice of teachers is unequivocal in order to have more hours of practice and confrontation with the practice at secondary schools in their preparation for the

teaching profession at the expense of purely theoretical subjects that seem to be separated from real practice.

- Teachers positively perceived the possibility of mutual encounters and certain confrontations in workshops and shading, where a number of selected topics were discussed, including examples of how to handle such situations and inspiration, including recommendations for teachers' future attitudes in the discussed cases.
- Teachers who have experienced shadowing, attendance, exemplary classes of our teachers in the past have positively assessed their good readiness for a pedagogical profession.

## 4 Conclusion

Effective education and training is based on a high level of training for pedagogical staff in a number of areas. This is related not only to the need for developing pedagogy as a science, but also to extend and improve its teaching at all types and levels of technical schools, especially at higher technical schools and universities. The constitution of the "information society" and the "knowledge society" requires - in the technical, human and social spheres - higher intervention of pedagogical knowledge and activities as well as a more dynamic development of pedagogy itself.

Students positively evaluated the benefits of educational activities, realized within the Fund of Educational Policy of Ministry of Education, such as lectures and attractiveness of the offered topics, the possibility of linking theory with practice, the opportunity to discuss with leading experts, their passion, not least portability of these outputs into practice. Many students appreciate that these are issues that they perceive as highly relevant for the teaching profession.

The interviews clearly show huge demands on the current teacher, both in professional competence and in the field of socially free features and other demands on future teachers. The preparedness of CTU students for the pedagogical profession is very good in the context of the interviews. In the future, it will probably be necessary to put even more emphasis on the number of hours of pedagogical practice and the preparation of teachers in cooperation with secondary education.

## References

1. ANDRES, P.: Připraveni (nejen) do učitelské praxe. Pražská technika 2/2017. Odborný časopis ČVUT. 1. vyd. Praha: Nakladatelství ČVUT (2017). ISSN 1213-5348
2. Andres, P., Svoboda, P., Vališova, A.: Snižování studijní neúspěšnosti a celoživotní vzdělávání na ČVUT v Praze. Sborník příspěvků z mezinárodní vědecké konference EDUCOM 2015. Pedagogica actualis VIII. 1. vyd. Trnava: Univerzita sv. Cyrila a Metoda v Trnave (2015)
3. Andres, P., Svoboda, P.: Vybrané aspekty celoživotního vzdělávání učitelů - techniků. In: Danielova, L., Schmied, J. (eds.) Sborník příspěvků ze 7. mezinárodní vědecké konfer-ence celoživotního vzdělávání Icolle 2015. 1. vyd. Křtiny: Mendelova univerzita v Brně, s. 17–34 (2015). ISBN 978-80-7509-287-8

4. Semrád, J., Vališová, A., Andres, P., Škrabal, M., a kol.: Výchova, vzdělávání a výzvy nové doby. Brno: Paido (2015). ISBN 978-80-7315-258-1
5. Moderní Vyučování. CZ: Škola hrou? S moderními technologiemi je to snadné (2016). http://www.modernivyucovani.cz/skola-hrou-modernimi-technologiemi-je-snadne/. Accessed 2 Feb 2016
6. Vašutová, J., a kol.: Vzděláváme budoucí učitele. Nové přístupy k pedagogicko - psychologické přípravě studentů učitelství. Praha: Portál (2008). ISBN 978-80-7367-405-2
7. Svoboda, P., Andres, P.: Multimedia as a Modern Didactic Tool – Windows EDU Proof of Concept Project at Czech Technical University in Prague. In: 19th International Conference on Interactive Collaborative Learning and 45th IGIP International Conference on Engineering Pedagogy, ICL2016. 1. vyd. Villach, Austria: IGIP (2016). http://www.springer.com/gp/book/9783319503394?wt_mc=Internal.Event.1.SEM.ChapterAuthorCongrat. ISBN 978-3-319-50339-4 (e-book 978-3-319-50340-0). ISSN 2194-5357 (electronic 2194-5365)
8. Vališová, A., Svoboda, P., Andres, P.: Application of ICT at contemporary schools in the Czech Republic. In: International Conference SCHOLA 2016 Pedagogy and Didactics in Technical Education. 1. vyd. Praha, Czech Republic: Taktiq Communications s.r.o. (2017). https://spark.adobe.com/page/7ohkpMA0lD2Wl/. ISBN 978-80-01-06112-1
9. Sharples, A.: Ferguson and team. INNOVATING PEDAGOGY: Open university innovation report 3 (2015). http://www.open.ac.uk/blogs/innovating/. ISBN 978-1-4730-0335-4. Accessed 15 May 2015
10. Melezinek, A.: Inženýrská pedagogika. Překlad: Božena Coufalová, Dana Dobrovská, Jiří Vacek. 2. přeprac. vyd. Praha: Vydavatelství ČVUT (1994). 179 s. ISBN 80-01-01214-X
11. Průcha, J.: Učitel. Současné poznatky o profesi. 1. vyd. Praha: Portál (2002). 160 s. ISBN 80-7178-621-7
12. Řezánková, H.: Analýza dat z dotazníkových šetření. 2. vyd. Professional Publishing, Praha (2007). 217 s. ISBN 978-80-7431-019-5
13. Andres, P., Dobrovská, D.: Dilemmas of student technical and social science thinking. In: 44th IGIP International Conference on Engineering Pedagogy, 2015 World Engineering Education Forum WEEF, Florence, Italy, pp. 99–101 (2015)
14. Svoboda, P.: Cesty hodnocení. Media4u Magazine, 7. ročník, 1/2010, s. 45 – 46 (2010). http://www.media4u.cz/aktualvyd.pdf. ISSN 1214-9187. Accessed 31 Mar 2010

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