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Grand Challenge Problems in Technology-Enhanced Learning II: MOOCs and Beyond

Perspectives for Research, Practice, and Policy Making Developed at the Alpine Rendez-Vous in Villard-de-Lans

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Grand Challenges in Technology-Enhanced Learning: A Dialog Started in Villard de Lans

Julia Eberle, Kristine Lund, Pierre Tchounikine and Frank Fischer

Abstract This book is the result of the Alpine Rendez-Vous 2013—a scientific event for European researchers in the field of technology-enhanced learning (TEL). The objective is to continue stimulating collaboration among TEL researchers and to move toward uniting the interdisciplinary TEL field. Event participants describe 12 socio-technical Grand Challenge Problems (GCPs) related to learning and to the educational system covering a wide range of topics. They focus on the improvement of learning and teaching in classrooms by technological means, the development of innovative TEL environments, updating the perspectives of TEL stakeholders, and the improvement of TEL research practices. Experts with backgrounds in either research, practice, or policy making comment on the 12 GCPs.

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This is already the second book on Grand Challenge Problems (GCPs) in Technology-Enhanced Learning (TEL). Just like the first, this second book is also an outcome of an Alpine Rendez-Vous—a scientific event for mainly European TEL researchers that has been held biannually in the Alpine region since 2007. The objective of the Alpine Rendez-Vous has been to stimulate exchange and collaboration among TEL researchers and to move toward uniting the interdisciplinary field of TEL by building a bona fide European TEL research community. This second book is the outcome of the Alpine Rendez-Vous 2013 which brought together 156 researchers with backgrounds in psychology, information technology, education, computer science, learning sciences, and other fields from Europe and beyond. During the Alpine Rendez-Vous 2013, researchers participated in at least one of the ten two-day workshops about specific TEL questions that were held in two parallel groups. However, while isolated in a hotel in the small French village of Villard de Lans, the researchers also used the time to look beyond their own research interests and discussed questions of TEL across workshops.

As the European TEL research community is still young and TEL research is diverse and scattered over several disciplines, the Alpine Rendez-Vous events are an important tool for community building and strategizing for future research directions. Therefore, we think it is important to make sure that the results of this event are accessible to those who are interested in TEL but who did not participate in the 2013 event. We have in mind not only TEL researchers but also other stakeholders who could benefit from TEL research.

Continuing the tradition started at the previous Alpine Rendez-Vous in 2011, we asked all workshops to come up with a short paper that describes what the participants see as the most important GCP for current TEL research. GCPs in TEL go beyond mere research projects and "are fundamental socio-technical problems whose solution will lead to breakthroughs that improve learning and educational systems and bring long-term benefits to society" (Zirn et al. 2014, p. 1). A GCP needs to be achievable in incremental steps that come with measurable outputs along the way of a mid-term agenda. GCPs can usually only be tackled in interdisciplinary collaborative efforts of researchers, practitioners, policy makers, and other stakeholders.

Each workshop undertook the task of developing a GCP in its own way, either by discussing among all participants or by giving the responsibility to a smaller group of the participants who took over the task. As a helping hand, each workshop had a *provocateur*[1] who was familiar with the idea of a GCP and his or her role was to support the development of the workshop's own GCP. Each workshop came up with a GCP, some even with two, resulting in 12 GCPs that are reported in this book.

The 12 GCPs 0 topics in TEL. Several GCPs attempt to **improve learning and teaching in classrooms by technological means**: In GCP 3, Pedaste and

[1]French for "challenger".

colleagues identify the challenge of empowering science teachers to use technology to scaffold inquiry learning. They suggest developing a platform-independent virtual teaching assistant with expertise on theories of learning and teaching and the capability to use learning analytics for adaptive scaffolding. In GCP 4, Cuendet and Tormay address the problem of sub-optimal teaching especially by novice teachers in the classroom. Their suggested solution is technology-supported visual feedback to teachers on emotional states and on attention distribution in their classroom. In GCP 11, Wasson, Hanson, and Mor focus on the challenge for teachers to make meaningful use of the increasing amount of student data available through ICT-based learning. They argue for the development of new measurement and analysis tools, accompanied by respective teacher training. In GCP 12, Molenaar and Wise point out that currently, teachers need to sacrifice a lot of potential teaching time for testing students and at the same time lack robust means of testing. They propose to assess student learning through continuous collection and interpretation of temporal performance data produced during learning processes.

Another set of GCPs focuses on (**further**) **development of innovative TEL environments**: In GCP 2, Chanel and colleagues draw our attention to emotion regulation as a social skill that is specifically important in social media. The authors suggest supporting the development of emotional skills with adaptive technologies to increase emotion awareness in collaborative learning environments. In GCP 6, Dehler Zufferey and Schneider formulate the challenge to bridge the gap between school-based and work-based learning contexts in vocational training to foster apprentices' identity building and integration into relevant communities of practice. They advocate for developing technological means to support apprentices and other stakeholders in bridging between the different learning locations in collaborative efforts among all stakeholders. In GCP 7, Mödritscher, Luengo, Law, Hoppe, and Stegmann discuss the challenge in response to the massification of university education by high-quality massive open online courses (MOOCs) that avoid drop-outs and support personalized learning experiences. The authors suggest developing tools based on learning analytics to support teachers and learners in MOOCs.

Some GCPs even go beyond classical research-related challenges. These GCPs focus on **decision and policy makers as well as practitioners, and other stakeholders** involved in the design of the educational system and the technology that increasingly surrounds us and propose to **update their perspectives** in a way that it is in accordance with the current scientific state of the art: In GCP 1, Giovanella, Martens, and Zualkernan focus on how learning can co-evolve with the rapidly advanced concepts of smart cities. They suggest combining functionalist views on optimizing the consumption of primary resources with more bottom-up perspectives of communities and the individual within a community. In GCP 5, Schneider and Dehler Zufferey identify the transformation of the currently outdated vocational education systems in Europe into systems that are more adequate for an information and communication society as a grand challenge. They suggest focusing especially on collaboration among all stakeholders in the re-design of new vocational education systems and extensive teacher training to implement the new view on vocational training. In GCP 9, Beetham, Perrotta, and Holley draw our attention to the problem that TEL may lead to educational inequalities. The authors suggest developing models for TEL stakeholders to identify and adequately respond to causes of inequalities.

A fourth set of GCPs specifically targets the **improvement of TEL research practices**: In GCP 8, Mödritscher, Luengo, Law, Hoppe, and Stegmann point out that the use of Learning Analytics on a certain group of learners does not often respect ethical requirements (e.g., learners are not always aware that their behavior is analyzed). In spite of this, they suggest widening the use of Learning Analytics from only focused on learners to also include the analysis of teacher behavior in order to engage both parties in interactive processes beneficial for learning and to support responsible use of Learning Analytics. This implies that ethical requirements be more generally understood and applied across stakeholders. In GCP 10, Dirckinck-Holmfeld and colleagues focus on the challenge to foster systematic and applicable TEL research across the many small and medium sized European research labs. Their suggested solution is the development of an agile and productive knowledge infrastructure for networking among the TEL research labs.

For the second part of the book, we asked experienced TEL researchers (Mike Sharples and Nicolas Balacheff), expert practitioners (Mikko Ripatti and Peter Schwertschlager, both principals of secondary schools, the first in Finland and the second in Germany), and a proficient policy maker (Lieve van den Brande), to comment on the 12 GCPs and share from their perspective what trends they see in the GCPs, how they think pushing these GCPs forward can be beneficial, and what they think is still missing. Across the different perspectives, the experts agree that there is currently a big gap between reality in schools and the outside world regarding the use and importance of technology and this gap needs to be closed. While each expert clustered the topics covered in the GCPs in their own way, several of them identified a trend of looking at big data in the form of learning analytics in the GCPs which brings new opportunities to teaching and learning but also comes with new dangers that must not be overlooked. Another trend that was identified by several commentators was the disappearance of the borders between formal and informal learning and a push toward more personalized learning experiences. This kind of learning is often much more self-regulated than traditional learning forms and especially the practitioners emphasize that it is highly demanding for learners and the preparation for self-regulated learning is a GCP on its own as well as the preparation of teachers for innovative ways of teaching, based on TEL.

The experts stress that the current situation in schools regarding laws of data protection and especially equipment is far from ready for implementing TEL and this is not sufficiently addressed by the GCPs. In addition, the danger that one may think TEL can eventually replace teachers instead of empowering them with technology is something to be reckoned with. In general, the experts express critically that although all GCPs attempt to be learner-centered, many of them put technology in the foreground and learning processes and the real needs of learners follow.

This situation emphasizes the need for more collaboration among the different disciplines in TEL research as well as the need for collaboration with stakeholders outside of research, with practitioners and policy makers given the possibility to influence the current TEL situation.

Despite these critical remarks, the interesting collection of GCPs reflects to some extent that the community building among European TEL researchers is progressing. Only half of the developed GCPs deal with classical TEL research-related questions, i.e., the improvement and development of learning environments. The second half, however, focuses on the one hand on internal community challenges that need to be tackled and to an even greater extent on the transfer of internal community knowledge to those people who need to take the next steps to implement the research findings so that society can benefit from TEL researchers' efforts. This last aspect can especially be interpreted as a sign that the TEL research community has left the phase in which the individual members need to understand how to benefit from collaborative efforts in the community. The TEL community seems to have progressed to a productive performing phase by starting to tackle the problems that are important for the whole scientific community. The 12 diverse GCPs have the potential to stimulate new collaborative projects within and beyond the TEL research community. Furthermore, the increased awareness of TEL researchers of the different perspectives and needs among TEL stakeholders raises the chances for successful collaboration that takes these needs into account and will eventually lead to a growth in the practical impact of TEL research. These developments give hope that TEL research will continue to attract funding by the EU and national funding agencies.

In a multidisciplinary field as dynamic as TEL, new technologies and new ideas are co-evolving very quickly. Dialog is the mechanism to establish and maintain flexible linking between researchers of different disciplines. This book is intended to continue and broaden a multidisciplinary dialog that has begun at the Alpine Rendez-Vous in Villard de Lans.

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Grand Challenge Problem 1: People Centered Smart "Cities" Through Smart City Learning

Carlo Giovannella, Alke Martens and Imran Zualkernan

Abstract The increasing smartness of cities and territories is driving the change of all aspects of learning: places, processes, approaches and methods, contents, roles and skills. The grand challenge (GC) is to develop an adequate governance of such transformation and through learning disseminate a "person in place centered" perspective to inspire the design and development of smart cities that are inclusive and supportive of the whole complexity of the human being and where formal and informal learning agencies integrate and cooperate to foster social innovation.

Today's "Smart Cities" (SCs) models promise to preserve and improve the society's well-being (Lee et al. 2008; Giffinger and Gudrun 2010). Most models adopt top-down functionalist approaches, aimed at optimizing the consumption of primary resources (energy, water, materials, food, and time through the thinning of **people**-, goods-, and data-flows). Mass education is identified with "transfer of information" to smart consumer-citizens. It is evaluated in terms of advanced infrastructure and the availability of related services (e.g. Internet). Benchmarks are: infrastructures (e.g. schools, universities) and efficiency (e.g. number of people with a university degree) (Giffinger and Gudrun 2010; Hollands 2008). Individuals and communities play no significant role.

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The Grand Challenge (GC) is the integration and fusion of the functionalist top-down vision of the SCs with a more bottom-up vision, a "person in place centered" design to obtain smart cities that are inclusive and supportive of the whole complexity of the human learning. This also requires a stronger coupling between formal and informal learning.

Problems of the European Education System Addressed and Long Term Benefits for Society

Transforming learning according to the increasing smartness of the cities is the core problem of the European Education System. Aspects of this transformation can be found in e.g. in the transformation of places, processes, approaches and methods, contents, roles and skills, in a person-in-place centered,[1] local (Robertson 1997), co-evolutive and social perspective.

We can distinguish three main themes:

1. Place and Content: evolution of contents and of their significance, also as a function of contexts and situations and the integration of the urban spaces with "ad hoc" redesigned spaces of the formal learning[2] (JISC 2006; Mäkitalo-Siegl et al. 2010). Expected benefits: recovering of the ability to read the territory in all its components; increase of social cohesion; stimulation of inclusion, integration, and sense of belonging; drop-out reduction.
2. Roles and Skills: redefinition of roles and skills of the actors (teachers, students, etc.) taking part in the learning processes. Expected benefits: ability to "manage" more collaborative and "ubiquitous" learning process; acquisition of skills needed to become smart learner and citizen).[3]
3. Monitoring and Evaluation: switch from predictive assessment to a multi-dimensional monitoring focused on the detection of emergent behaviors. Expected benefits: foster individual motivation, self-confidence, and social awareness and, progressing with the age, a higher degree of self-regulation (Zimmermann 1990); produce a more inclusive and aware society.

[1]The origin of the "Person in Place Centered Design" vision is documented in Giovannella (2008) and later in Giovannella and Graf (2010).

[2]See http://vittra.se/english/VittraEnglish.aspx and http://fcl.eun.org.

[3]See http://en.wikipedia.org/wiki/Life_skills and http://disco-tools.eu/disco2_portal/terms.php.

Main Activities to Address the Grand Challenge Problem

Increase the awareness among stakeholders, e.g. policy makers and companies and promote a network among the initiatives supporting a people centered view (not necessarily related to learning[4]). Promote the identification and adoption of smart learning indicators that can contribute to benchmarking[5] (Giffinger et al. 2007; Quality of Life in Twelve of New Zealand's Cities 2007).

In more detail:

(A) Related to aspect 1.:

A.1: Build participatory evolutionary contents, go beyond Web 2.0 practices, foster integration between formal and informal learning;
A.2: Interlace content to urban spaces, considered as open and interactive "books"[5] (Iosue et al. 2012; Giovannella et al. 2013), made sensible and responsive by "embedded" technologies (Weiser 1993; Greenfield 2010; Shepard 2010);
A.3: Study of the cultural mediating role of technologies[6] (e.g. in removing barriers, stimulate attention and curiosity, etc.), increase social cohesion, integration, and sense of belonging.

(B) Related to aspect 2.:

B.1: Unified classification of skills needed by actors with different roles (Giovannella and Baraniello 2012);
B.2: Priorities for skill acquisition.

(C) Related to aspect 3.:

C.1: Describe learning experiences with the help of a model, to include individual styles, social characteristics, context and process peculiarities (Giovannella 2012);

[4]For a "human smart city" vision see http://www.peripheria.eu/library, retrieved on August 20, 2013 (get inspiration also from the Human Centered Design Vision by IDEO at https://hcd-connect-produc-tion.s3.amazonaws.com/toolkit/en/download/ideo_hcd_toolkit_final_cc_superlr.pdf); for a "human smart city" vision applied to small communities see http://my-neighbourhood.eu; for a "citizentric vision" see http://urban360.me.

[5]Smart Cities is a North Sea Intereg 4B project (2007–2013) http://www.northsearegion.eu/ivb/projects/details/&tid=84.

[6]See papers included in the IxD&A Journal special issues on "Smart City learning", N. 16 and N. 17, available at http://www.mifav.uniroma2.it/inevent/events/idea2010/index.php?s=102&link=ToC_16_P.

C.2: Identify indicators of/strategies to:

C.2.1: Monitor relevant dimensions of the learning (Shepard 2010; Giovannella et al. 2011) and skill transformation;
C.2.2: Detect the increase of social cohesion and critical situations, included drop-out precursors;
C.2.3: Develop meaningful analysis and representations;
C.2.4: Barriers related to personal data (balancing of privacy preservation and collective advantages)

Promotion of a worldwide monitoring action aimed at the collection of the best practices and pilots, the elaboration of blueprints, and the sharing of the knowledge. To this end we have created an International Observatory on Smart City Learning and the Association for Smart Learning Eco-systems and Regional Development (ASLERD).[7]

Timeframe for the Grand Challenge Problem

We expect SCL models and blueprints to be developed till 2016 while for the realization of first prototypes and implementation of pilots, the timeframe is likely to be 2017–2020, provided that the issue of Smart City Learning will be soon included in the mainstream activities promoted by the DG Connect and by the National Governments.

Measurable Progress and Success Indicators

The number of:

- stakeholders involved
- events
- number and quality of publications

In detail, regarding the three classes:

1. Redefinition of the format of the learning contents and their integration within technology augmented urban spaces; effects of the people centered Smart City Learning on social cohesion, integration, and sense of belonging and, as well, motivation of learners and the drop-out rate;
2. Definition, acquisition, and/or transformation of the skills needed to become pro-active actor of the Smart City Learning processes;

[7]See International Observatory on Smart City Learning: http://www.mifav.uniroma2.it/inevent/events/sclo/index.php.

3. Monitoring of each of the dimensions of the learning experience and of the effects on Smart City Learning on self-regulation.

Attraction of Funding

Currently the main goal is to raise awareness among stakeholders—citizens, policy and decision makers, industries—and attract them by pointing out (through the organization of debates, focus meetings, etc.) the benefits all can have from the integration of Smart City Learning within the mainstream of SC development.

In parallel one could attempt to raise funds: (a) by promoting case studies that engage policy makers, professionals, and entrepreneurs; (b) through the development of an international network interested in technology transfer (e.g. concepts, prototypes, and pilots related to the SCL); (c) through the adoption of targeted crowd-funding strategies.

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Grand Challenge Problem 2: Adaptive Awareness for Social Regulation of Emotions in Online Collaborative Learning Environments

Guillaume Chanel, Denis Lalanne, Elise Lavoué, Kristine Lund, Gaëlle Molinari, Fabien Ringeval and Armin Weinberger

Abstract Students' ability to understand and manage emotions in self and others plays an important role in the success of collaborative learning. In online learning environments, the access of socio-emotional cues is reduced, and this may lead to a lack of emotion awareness that could be detrimental to collaboration and learning performances. The project we present here aims at substantially improving learning effects with social media through the use of adaptive emotion awareness technology designed to support students' emotional regulation in online groups.

Keywords Computer-supported collaborative learning · Affective computing · Emotion awareness · Emotion management · Multi-modal interaction

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Students' ability to understand and manage emotions in self and others plays an important role in the success of collaborative learning (Järvenoja and Järvelä 2009; Lajoie et al. 2015; Lavoué et al. 2015). In online learning environments, the use of new social media technologies (blogs, forums, wikis, social networking sites, etc.) facilitates connections between learners, but may also introduce new communication challenges. Moreover, the access of emotional cues (e.g., interest, workload, stress, anxiety) is reduced in such environments. Online collaborative learners may therefore experience difficulties in evaluating their partners' emotions and adjusting their behavior in response. A lack of emotion awareness among online learners may have a detrimental effect on collaboration and learning (Eligio et al. 2012). It may also lead to inappropriate or even dangerous social behaviors such as cyber-bullying. This project aims at substantially improving learning effects with social media through the use of adaptive emotion awareness technology (Chanel et al. 2013; Ringeval et al. 2013) designed to support students' emotional regulation in online groups.

Problems of the European Education System Addressed and Long Term Benefits for Society

The increasing use of social networking sites introduces new social problems such as cyber-disinhibition and cyber-bullying that interfere with school and learning. Such problems are based on failure to address the development of socio-emotional skills in school curricula. A new pedagogy is needed that is based on self-regulated, experiential learning in groups where learners are supported to achieve a deeper understanding of self in relation to others. In order to contribute to the goal of building emotion-centered learning programs, research should focus on the investigation of how awareness tools can be adapted to support the social regulation of emotions in online learning contexts (Molinari et al. 2013).

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Main Activities to Address the Grand Challenge Problem

There will be five main activities:

1. Selection of a population of learners involved in online collaborative learning experiences. An assessment will be conducted targeting learners and groups of learners with emotional regulation problems.
2. Investigation into the role of emotions in online social learning environments. The output will be a range of emotions identified as playing a significant role in the success of collaborative learning.
3. Development of methods to identify learners' emotions in real time during online collaborative learning. These methods will be based on a multimodal dynamic analysis approach including signals from users (e.g., facial expression, speech, eye movements, physiological data) and contextual information. A focus will also be on how co-learners' emotions evolve over the course of their interactions.
4. Development and implementation of adaptive emotion awareness systems. To be efficient, they should promote the sharing of emotions identified as beneficial to collaborative learning at the proper time during interaction.
5. Evaluation process of systems developed in (4) and with participants selected in (1), using the following criteria: users' acceptance; capacity to enhance mutual emotion awareness and collaborative learning; capacity to help students deal with emotional issues in online social learning environments.

Timeframe for the Grand Challenge Problem

The proposed Grand Challenge Problem could be solved in a timeframe of 4 years: 6–12 months for Activity 1 (Year 1), 24 months for Activity 2 (Years 1–2), Activity 3 (Years 2–3), Activity 4 (Years 3–4), and 12 months for Activity 5 (Year 4).

Measurable Progress and Success Indicators

1. Development and validation of models for the investigation of the dynamics of emotions and their regulation in computer-supported collaborative learning (CSCL) contexts.
2. Development of adaptive emotion awareness systems for various types of CSCL environments, implementation of studies to assess their acceptance and usefulness in laboratory and authentic settings.
3. Higher emotion awareness, better collaborative processes, and learning outcomes in CSCL settings.

4. Development of a methodology for the assessment of skills for social regulation of emotions in online learning contexts, development of emotion-centered learning programs.
5. Development of an interdisciplinary research community working on awareness tools for regulation of emotions in CSCL.

Attraction of Funding

Interdisciplinary European projects funded under the European Commission (e.g., H2020-ICT, Lifelong Learning Programme such Comenius, Erasmus, or Grundtvig); COST (European Cooperation in Science and Technology) fund for covering the cost of networking activities; National funding, e.g., Swiss National Science Foundation (SNSF), French National Research Agency (ANR); Funds for applied R&D, e.g., Hasler Foundation in Switzerland which supports educational, research, and innovation projects where the aim is to promote the development of ICT or innovative applications of ICT.

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Grand Challenge Problem 3: Empowering Science Teachers Using Technology-Enhanced Scaffolding to Improve Inquiry Learning

Margus Pedaste, Ard Lazonder, Annelies Raes, Claire Wajeman, Emily Moore and Isabelle Girault

Abstract Inquiry learning in technology-enhanced learning (TEL) environments has potential to support science learning. The "symbiosis" between teachers and TEL environments is needed and, therefore, virtual assistants should be "taught" based on pedagogical theories. These assistants should be dynamically integrated with various learning environments to empower teachers and to provide effective scaffolding to every student during inquiry. Outcomes provided by the student or teacher could serve as input for the virtual assistant in addition to logging of student and teacher interactions. The virtual teacher assistant should be developed in collaboration between researchers and commercial software developers using joint research and development grants.

Keywords Inquiry learning · Technology-enhanced learning environments · Scaffolding · Virtual assistant

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Science learning should be engaging for all students and support responsible research and innovation practices in everyday life. Inquiry learning has been a successful approach in science education (Alfieri et al. 2011), and technology-enhanced learning (TEL) environments have potential to support learning from both the teachers' and learners' perspectives (De Jong 2006). TEL and teachers should be "friends" and act in "symbiosis" to scaffold and motivate learners to relate their careers with science. TEL-environments should involve virtual teacher assistants that analyse and respond to individual learners to create meaningful learning activities. Virtual assistants have shown some success in the context of specific learning environments (Pedaste et al. 2013). However, an ultimate challenge is to develop a teacher assistant that can be "taught" based on specific pedagogical theories and dynamically integrated with various learning environments. This innovation is needed to empower science teachers with the capability of providing effective scaffolding for every student during inquiry.

Problems of the European Education System Addressed and Long Term Benefits for Society

Science, technology, engineering and mathematics (STEM) are reported as key sources for technological innovation in the twenty-first century. However, the European education system fails in motivating enough young citizens towards careers in STEM. TEL-environments are needed as they provide appropriate scaffolds to guide students in learning while engaging in authentic learning activities. Presence of a re-usable teacher assistant would have several long-term benefits: increased efficiency of teaching, individualized learning experiences for students, improved scientific literacy, increased authenticity of the learning process and better informed citizens—prepared for career decisions and to use scientific thinking throughout life.

Main Activities to Address the Grand Challenge Problem

Three main phases are specified. First, several TEL-environments are already available that provide students with innovative approaches for learning science and other STEM topics. Some existing TEL-environments will require revision and re-design, to more uniformly meet the needs of inquiry-based STEM education. Second, a stand-alone virtual teacher assistant should be designed on the basis

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of existing principles based on pedagogical theories for inquiry-based learning. This virtual assistant will include integration with various TEL-environments, an easy-to-use design to support teachers, and utilize learning analytics to scaffold learners. Outcomes provided by the student or teacher could serve as input for the virtual assistant in addition to logging of student and teacher interactions. Data collected by the virtual assistant should be stored and re-used to improve future learning analytics. Third, teachers' professional development should be enhanced in order to apply the virtual assistant in a symbiotic way that empowers teachers. All three phases should be supported by research projects to enhance understanding of inquiry-based learning, development of guidelines for seamless integration of virtual tools into teacher practice and classroom implementation, and effective professional development strategies for complex human–computer interaction.

Timeframe for the Grand Challenge Problem

The re-design of existing learning environments and the design of a virtual teacher assistant can start in parallel and last about four years. A teachers' community should be recruited during the following two years. The training of the community through four years is needed to implement the assistant effectively.

Measurable Progress and Success Indicators

In all phases of solving the grand challenge problem, the increased competency levels in the context of scientific and technological literacy of teachers and students will be measured. The community building and teacher training phases can be evaluated through the number of teachers involved and trained according to the new paradigm. The use of the virtual assistant in research projects and research publications could be an indicator of success. Over the long term, the number of students who pursue and obtain careers in STEM fields should be monitored.

Attraction of Funding

The first developmental phase of the virtual teacher assistant should be attractive to commercial software developers where a large demand for the end-product can be expected. However, the work can also be financed through European Unions' funding schemes; e.g. EU HORIZON 2020. Teachers' training can be supported by Lifelong Learning programmes such as Erasmus+. However, several national funds can also be used to empower teachers with a tool like virtual teacher assistant if it has a scientifically proven positive effect on learning achievement.

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Grand Challenge Problem 4: Supporting Teacher Decision-Making Through Appropriate Feedback

Sébastien Cuendet and Roland Tormey

Abstract The quality of teaching is significantly enhanced through feedback to teachers about their teaching. Whereas systems to show student learning exist, those showing the emotional state of the classroom do not. We argue that such systems could greatly improve teaching, and in consequence, pupil attainment. Data for such system could come from biometric sensors or from cameras and microphone monitoring the gaze of students, their restlessness, and the level of noise in the classroom. Such systems would be valuable in particular for teachers with less experience.

Keyword Teacher feedback

The quality of teaching is significantly enhanced through feedback to teachers about their teaching—in fact, feedback to teachers has been found to have a bigger impact on pupil attainment than any other type of teacher-based intervention (Hattie 2009). This feedback is most effective when it is based upon data and when it is presented in graphical formats. The feedback presented to the teacher can include information of two kinds. The first one is information on student learning, and the second one is information on the emotional state of the classroom. While the benefits of feedback on learning are obvious, teacher relational skills and classroom climate also have a significant impact upon pupil learning (Cornelius-White 2007). Recognising emotional states in others is a key element of teacher emotional competence, and one in which novice teachers appear to perform poorly (Corcoran and Tormey 2012).

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Systems gathering students' performance already exist, and the challenge at hand is more on how to develop visualisation tools that allow the teacher to quickly and accurately evaluate her/his students' learning performance and to adjust their teaching appropriately. Effective systems to gather useful information about the emotional state in the classroom do not exist yet and would need to be developed. For example, the data could come from biometric sensors or from cameras and microphone monitoring the gaze of students, their restlessness and the level of noise in the classroom. These data would then be transformed by algorithms to show a map of the global attention level in the classroom.

This feedback would be useful for all teachers, but would be particularly valuable to young teachers, or teachers in training. Indeed, experienced teachers are often able to recognise information that is missed by non-teachers or novices (Sabers et al. 1991). Feedback, which could help novice teachers to recognise key features of the classroom environment, could play a significant role in teacher professional development.

Problems of the European Education System Addressed and Long Term Benefits for Society

1. More effective models of feedback to teachers are likely to raise educational attainment, and to aid in the development of a European knowledge-based society.
2. Education systems and practices are different across Europe. Collecting data on pupils' learning and engagement across countries would allow comparing the various practices and their outcomes based on hard data, and provide greater evidence on how class climate impacts upon learning.
3. Teachers' longevity in the job can be rather short. There is evidence that greater skills in management of the emotional state of the classroom can help teachers stay longer in the job.

Main Activities to Address the Grand Challenge Problem

- Development of systems for gathering real-time classroom-based learning and affective data.
- Development of systems for gathering real-time classroom-based affective state of the teacher.
- Development of feedback systems for teachers that provide just-in-time data in non-intrusive ways.
- Development of systems for data-based feedback to facilitate post-lesson reflection for initial and ongoing training of teachers.

- Development of practices for use of such tools which are relevant to various schools, subjects and national cultures.
- Documentation of existing privacy policies and their impact on these systems and development of privacy and usage policies and practices for the data collected by the systems.

Timeframe for the Grand Challenge Problem

The development of some of the systems has already started. Developing more systems will take any time between 2 and 5 years. Documenting the impact of current policies, creating new ones and activating them will rather take between 5 and 10 years.

Measurable Progress and Success Indicators

The number and the quality of the systems developed, as well as the type of information they will give to teachers.

- An increased longevity and well-being for teachers.
- An increased homogeneity among students' results due to the higher competency level of teachers.

Attraction of Funding

The development of such a project can be funded through a European project or national calls.

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Grand Challenge Problem 5: Bringing the Information and Communication Society to Vocational Education and Training

Daniel Schneider and Jessica Dehler Zufferey

Abstract Can we imagine that learners, in particular in the vocational education and training (VET) sector, could become active "connectivist" information workers that are able to manage information density, to contribute to organized knowledge and be part of extended communities of practice? As it stands today, social practice is fragmented, e.g., workplace, school, and research do not communicate very much. There are few "places" and opportunities where actors can connect, share, and build knowledge. But even if there were, very few would jump on the opportunity. How can we transform educational, workplace, and research practice to foster knowledge sharing and co-construction?

Kerwords Connectivism · Knowledge building community · Expansive learning · Information working · New scholarship · Use-inspired research · Design research

Since the advent of the Internet, society is slowly moving toward an information society that requires new skills, for example, being able to deal with information density or contributing to virtual communities of practice. The so-called "digital generation" possesses good communication skills that are focused on networking and sharing/trading of simple digital artifacts. However, it lacks information working skills (Selwyn 2009). It does not use technology to manage, acquire, share, and co-produce new knowledge. In addition, the traditional separation remains between the ones "that know" (teachers and supervisors) and the ones that "reproduce". Could we imagine that learners, in particular in the vocational education

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and training (VET) sector, could become active "connectivist" information workers? Could they be given a larger role in a community of practice that extends their school or immediate workplace? How can we adapt the research and development system so that it could address such a challenge?

Problems of the European Education System Addressed and Long Term Benefits for Society

The European education system reflects a pre-information society where stable explicit knowledge dominated. In vocational education, school is supposed to teach stable concepts; the workplace has to convey applied procedural knowledge, and the learner should bridge the gap and integrate. Large digital learning communities where both new and informal knowledge could connect do not exist. VET could benefit from the body of knowledge that exists in the heads of participants, made explicit. Teaching could draw on real-world experience. Professionals and apprentices could profit from new trends emerging in other locations. In other words, all stakeholders could interact more and better.

Main Activities to Address the Grand Challenge Problem

The first tasks are building a conceptual framework and launching long-term design studies. Connectivist learning and teaching frameworks (Siemens 2004; Downes 2012) that are, for example, implemented in so-called cMOOCs could be merged with theories on collective learning (De Laat et al. 2007), knowledge building community (Bereiter and Scardamalia 2003), and community of practice learning models (Wenger 2000). To insure adaption to vocational education, expansive learning projects (Engeström 2001) must be carried out in partnership with all interested stakeholders, including professional organizations, schools, teachers, learners, and researchers.

Vocational teacher and trainer education must be radically adapted to include technical and conceptual aspects of Internet use in education and practice. For starters, schools must be reorganized as a learning community that shares and connects experience among itself and with the workplace. Teachers and supervisors cannot teach with new models if they did not experience those themselves.

In the same vein, research must adapt to the problem and new ways of scholarship must be found to allow for long-term use-inspired basic research (Stokes 1997) as well as serious design research (Järvinen 2007). Scholars involved in the project must adhere to connectivist practice or else they will fail connecting theory to practice.

Timeframe for the Grand Challenge Problem

Design research studies can be done within the next 10 years. However, full implementation at the system level could be managed in 25 years from now, but may likely last longer (Burkhardt and Schoenfeld 2003).

We could identify the following milestones:

- Milestone 1 (5 years): Models that integrate learner activities with online sharable knowledge have been designed and implemented in some sites.
- Milestone 2 (10 years): Researchers and practitioners use "connectivist" means to co-create knowledge.
- Milestone 3 (25 years): Infrastructures where learners and professionals interact both in schools and at the workplace are designed, implemented, and used.

Measurable Progress and Success Indicators

Indicators for milestone 1: Knowledge co-construction activities represent a significant chunk of the curriculum and are conducted during the whole school year.

Indicators for Milestone 2: Researchers, teachers, and professionals use ICT for themselves and contribute actively to shared knowledge spaces. Isolated conference and journal publications will be shunned and evaluation of scholarly work will use new criteria, e.g., reputation systems for connected and open online contents.

Indicators for milestone 3: At least 20 % of professionals, apprentices, and classes in at least three VET sectors should be part of this new framework.

Attraction of Funding

In order to be successful, the funding scheme must encourage transformative design-based bottom-up research approaches and put in place new forms of academic recognition for new forms of knowledge co-construction.

National and regional systems should take part in the program and engage in educational reforms that take into account the changing nature of society and knowledge.

The challenge requires long-term financing of many relatively small projects that, however, must exchange through a common infrastructure. Therefore, we suggest lobbying for a different new research and design framework that is supported by both the EC and the main political education bodies in participating countries, for example in the form of some extension to the EC "Lifelong learning programme".

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Grand Challenge Problem 6: Technology to Bridge the Gap Between Learning Contexts in Vocational Training

Jessica Dehler Zufferey and Daniel Schneider

Abstract Dual systems of vocational training address procedural and conceptual knowledge in different contexts, the workplace and the professional school. Apprentices do often not succeed in integrating both types of knowledge. This lack can lead to motivation problems, missing cross-context knowledge transfer, and problems to develop a professional identity. We argue that "bridge-the-gap" technology has great potential. Successful action on this challenge should lead to widespread use of well-designed learning technologies, an increasing number of interactions between actors of different learning locations through artifacts and conversations produced within bridge-the-gap environments, less perception of separation between learning contexts by apprentices and more cross-context application of knowledge.

Keywords Vocational training · Bridge-the-gap technology · Erfahrraum model · Learning location · Participatory research

Learners in vocational training have to develop procedural as well as conceptual knowledge. In dual systems of vocational training, these two learning objectives are addressed in different contexts, the workplace and the professional school. In school-based vocational training, different types of teaching are attributed to the acquisition of either type of knowledge (lecture vs. lab work or internships).

Apprentices are supposed to, but do often not succeed in integrating both types of knowledge. During the training, this lack can lead to motivation problems,

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missing cross-context knowledge transfer, and problems to develop a professional identity and to grow into the community of practice. After the training, lifelong learning and constant expertise building are at risk.

We lack a deep understanding of how apprentices accomplish this integration process and which factors facilitate it. Consequently, there is little systematic support for this process. We argue that "bridge-the-gap" technology has great potential to do so.

Problems of the European Education System Addressed and Long Term Benefits for Society

Training systems tend to neglect the integration of different learning contexts and knowledge types. Research and practice to reduce the gaps in vocational training will benefit from the large body of knowledge in the field of technology-enhanced learning, in particular from integrative learner-centered approaches that aim to create deep and applicable knowledge. Training will be up to date regarding technologies. In a long-term view, innovations can be quickly implemented in the practice of vocational training. More generally, apprentices after their training will be competent to make use of technologies to support their work and lifelong learning. Insights from vocational training, in reverse, will be useful for any kind of competence-oriented education.

Main Activities to Address the Grand Challenge Problem

First, a conceptual framework is necessary, in order to coordinate activities among groups of actors (practitioners, policy makers, researchers) and define in detail the objectives. In current work, a first conceptual framework of technology support for the integration of different learning locations in vocational education (the "Erfahrraum" model) was contributed to the discussion in the scientific community.

Second, we need to develop technologies that support the integration of learning locations in vocational training. That includes the development of technological solutions that are addressing specific challenges of individual professions, their implementation, and accompanying evaluation. Experiences from implementations and design iterations need to be shared in order to come up with design principles for the future.

In parallel, the concerned community needs to be built and maintained. Researchers, policy makers, and practitioners share research results, practice experiences, policy conditions, etc. The transfer of knowledge between actors needs to be stimulated, for example by means of participatory research approach (as advocated by the European project on evidence informed policy and practice in education in Europe, EIPPEE) or workshop events.

On a political level, the actors from vocational training (professional schools, professional associations, teachers' associations) need to be supported, also in financial terms.

Timeframe for the Grand Challenge Problem

Conceptual framework: based on current work; scientific community agrees on a framework and starts to apply it (5 years).

Iterative Development: Synthesis of existing experiences from different countries and in different professional domains, complementing with design and evaluation studies (15 years).

Community and political support: continuous long-term task.

Measurable Progress and Success Indicators

Successful action on this challenge should lead to:

- the use of well-designed learning technologies for vocational training in most vocational training programs, and in particular "bridge-the-gap" technology made mandatory,
- an increasing number of interactions between actors of different learning locations through artifacts and conversations produced within bridge-the-gap environments,
- a higher number of community events with participants from different groups of actors (researchers, policy makers, and practitioners),
- less perception of separation between learning contexts by apprentices and more cross-context application of knowledge.

Attraction of Funding

European funding should be approached, with different partners from different countries. Countries should represent the range of vocational systems present in Europe. In each country, the research team should cover competences from technical domains and educational/learning sciences, as well as experts for vocational training. Funding for development and implementation should be approached from large associations representing many professions.

Grand Challenge Problem 7: Towards Adaptive and Adaptable Learning in Massive Online Courses

Felix Mödritscher, Vanda Luengo, Effie Lai-Chong Law, H. Ulrich Hoppe and Karsten Stegmann

Abstract European universities are facing a massification of education, which leads to classes with the size of more than 1000 students in massive online courses (or in short "MOCs", including the open version of MOOCs as a subcategory). This Grand Challenge Problem deals with the application of adaptive and adaptable educational technologies that exploit user-generated data in order to support individual and group learning in MOCs. The vision is to enhance MOC experiences in terms of efficiency and quality of study programs, including the fostering individual strengths of learners even in large cohorts of students with standardized materials.

Keywords Massive online courses · Adaptive and adaptable learning · Exploitation of user-generated data · Quality of study programs

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Adaptability and adaptivity are concepts which are known and applied in the field of education and for personalized learning for more than a century, as shown, e.g., with Sidney Pressey's apparatus for adaptive assessment of mechanical skills (Pressey 1926). Many macro and micro-adaptive approaches in learning-related software have been experienced and documented over the last decades (see Park and Lee 2008). However, system-driven personalization in the form of adaptive behavior in learning environments has also failed or been criticized in the past (cf. Wild et al. 2008).

This GCP deals with the application of adaptive and adaptable educational technologies that exploit user-generated data in order to support individual and group learning in massive online courses (MOCs). Hereby, MOCs are considered to be offered by higher education organizations, such as universities, as an additional service for fundamentals courses in Bachelor study programs that have more than 1000 students or even for massively open online courses (MOOCs) which are offered to a large audience for free. The vision of this GCP is to **enhance MOC experiences in terms of efficiency and quality of study programs**, including the consideration of **fostering individual strengths of learners** despite large cohorts of students and standardized materials.

Problems of the European Education System Addressed and Long Term Benefits for Society

European universities are facing a massification of education (cf. Johnson et al. 2012). Massification in the definition of this GCP is addressing but not restricted to classes with the size of more than 1000 students. Also sizes of 50 to 100 students are affected in the sense that human resources to provide one-to-one feedback by teachers to the students are costly. Consequently, running such large classes leads to (a) high dropout rates due to the absence of guidance, interactions, and feedback by teachers, (b) standardized instead of personalized learning experiences, and (c) students with a very superficial and shorter lasting knowledge.

Although various research projects in the European landscape address personalized learning and most of them include large test-beds, they are either restricted to adapting toward specific learner groups (e.g., workplace learners in ARISTOTELE or APOSDLE, game-based learners in 80 Days, lifelong learners in GRAPPLE, etc.) or adapting based on traditional factors like the learning performance (e.g., GRAPPLE or MIRROR), knowledge (e.g., TARGET or GRAPPLE), emotions (e.g., ALICE or MIRROR), and so forth.

Further challenges of MOCs address the change in the value of formal qualification due to MOC-based education and MOOCs, as well as the upcoming importance of e-portfolios and badges resulting from formal and informal learning activities. e-portfolios comprise digital collections of learning outcomes (i.e., competencies and artifacts) achieved by a learner (see Barrett 2010). Badges are awards given to the most excellent student(s) of a course, thus motivating learners to put more efforts on their favorite subjects and enabling them to distinguish themselves from their peers (cf. Rughinis 2013).

Particularly companies are in favor of being able to assess and value the competencies of academics on the basis of former learning experiences at universities, which could be achieved through certificates but also through e-portfolios or badges. Data-based approaches might be enabler for the 'learning-to-earning' scenario in which students of higher semesters get prepared for the job market through realistic task assignments and evidence for their competence development.

Main Activities to Address the Grand Challenge Problem

Above and beyond, this GCP should include the following activities:

- **Applying learning analytics** to support self-responsible learning of students, ensure fairness in the learning process (e.g., prevent cheating or standardize grading), and report progress of students' learning.
- **Strengthening the role of the teacher** as coach and provider of feedback, e.g., through an Analytics like approach
- **Supporting learners in making informed decisions** about their study plan.
- **Providing tools for managing competences and learning outcomes** for students in order to facilitate lifelong learning.

Instead of designing adaptive behavior of learning environments ex ante and according to factors of potential interest, this GCP should approach the development of new learning analytics functionality through analyzing large real-world data-sets about learning technology usage, if possible throughout and beyond study programs.

Due to the GCP's strong focus on MOCs, it is recommended to consider organizations from higher education and their learning management systems (LMSs). Findings to expect could comprise high correlations between learning outcomes and technology usage (Whitmer 2012), characteristics of specific user groups (web vs. mobile users) and seasonal effects (see Andergassen et al. 2013), or other factors that influence learning in a positive and negative way.

Concerning the implementation of this GCP, the following technical challenges can be identified:

- **Retrieving and preparing real-world data-sets** about learning in MOCs (including ethical aspects like privacy or anonymization of data)
- **Analyzing the data and deriving valid findings** for one or more factors influencing learning
- **Implementing and rolling out new learning analytics functionality** to support a personalized learning cycle which involves learners and teachers and to analyze changes in the educational landscape, e.g., by measuring the influence of new trends like MOOCs

- **Realizing and experiencing e-portfolio, badges, and competency management tools** for facilitating learning beyond the context of higher education.
- **Evidencing the Improvements in the MOCs** going beyond the scope of providing and enhancing MOCs, questions that arise concern the role and tasks of universities which have to manage courses with a large number of students but also the situation that learners can achieve competence development from elsewhere, e.g., through MOOCs. Among others, learning analytics solutions should be deployed in such courses to support self-responsible learning of students and keep track of their progress. Moreover, the role of teachers as coaches and feedback providers should be strengthened, and learners should be supported in making informed decisions in personalized learning scenarios.

Timeframe for the Grand Challenge Problem

The timeframe for implementing the GCP ranges from 3 to 7 years, depending on the application scenarios to address and the broadness to roll out prototypic solutions to evaluate the validity of the Grande Challenge.

Measurable Progress and Success Indicators

Progress and success of this GCP should be measurable at least through the following influences on these indicators (not limited to):

- The dropout rate in MOCs should decrease over time, thus saving a university or higher education institute money.
- The number of graduates should grow over years, thus also increasing the reputation of the university.
- The overall quality of the study program should increase, which could be measured through comparing the competence levels of students before and after introducing solution approaches based on this GCP.
- It is easier to reconstruct learning achievements of students through comparing the learning outcomes before and after introducing solutions for this GCP (e.g., grades vs. e-portfolios or badges).

Attraction of Funding

Funding can be attracted through traditional research initiatives, such as national or European funding schemas, or through cooperation with organizations from higher education.

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Grand Challenge Problem 8: Interactive Learning Analytics: From Accountability to 'Opportunity Management' in a Multi-actor Perspective

Felix Mödritscher, Vanda Luengo, Effie Lai-Chong Law, H. Ulrich Hoppe and Karsten Stegmann

Abstract Currently, many Learning Analytics (LA) initiatives are carried out throughout Europe. Typically, LA have been developed and are provided for one specific stakeholder group such as students or teachers of a university. In some cases the exploitation of technology usage data lacks the consideration of ethical issues, for instance if students are not aware that and how their data is being used by LA facilities. Against this background, this Grand Challenge aims at enhancing LA-related projects by broadening the view on LA, particularly concerning the involvement of stakeholder groups, issues of ownership, and related ethical questions.

Keywords Learning analytics · Opportunity management · Interactive multi-actor analytics process · Ethical issues

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Learning Analytics (LA) deals with applying business intelligence techniques, e.g. the measurement, collection, analysis, and reporting of learner interaction data, in order to predict performance of learners in educational activities and support them in decision-making (Ferguson 2012; Buckingham Shum and Ferguson 2012). LA approaches often end with the provision of a tool that provides numbers or visualizations to end-users (possibly including learners, tutors, teachers, curriculum designers, educational managers, policy makers), assuming that this feedback has a positive impact on a human's behavior or an organization's performance.

In spite of the acknowledged wide range of users of analytics results, data collection for LA has been largely focused on learner traces. However, there is no technical obstacle to widening the perspective toward analyzing multi-party interactions (i.e. including also the actions of teachers and tutors as objects of analysis). This could be considered as a "democratic turn", which would facilitate a better **management of accountability and opportunities in educational settings**. Not only would tutors and teachers be supported in reflecting on and improving their teaching activities, also learners could be included in dialogic process of quality management. As a further consequence, developers would be empowered to improve their educational software and content creators could be made aware of flaws in their learning materials, which might have a positive effect on the quality of study programs and the efficiency of the educational institution.

All these stakeholder groups should take an active part in **an iterative and** interactive Analytics process in order to improve learning. They are active agents who are engaged in contributing to the production of learning systems that can collect data, in producing data, in analyzing, interpreting, and making decisions that should lead to an improvement of the activities of each actor. Thereby, interactivity is required to extend the view on LA as a panacea for providing easy answers and to support the complex process of deriving valid interpretations in the right situation. Consequently, the resulting Analytics loop consists of steps like 'acting', 'deciding,' and 'providing Analytics'.

Besides investigating into specific characteristics of the stakeholders being involved in the Analytics process—like their decision-making capacity or their activeness in the learning process—this GCP addresses the **socially responsible uses of LA** (e.g., privacy and other ethical issues), **reflection and openness in professional behaviors and attitudes** in order to **create opportunities for change** and **make human responsibility explicit**. Shifting responsibility to the stakeholders is considered a motivational element to increase their efforts on their specific tasks in the educational system as well as their risk-taking in changing the environment to improve learning, while the Analytics measure and reflect their activities, thus strengthening their commitment. Hereby, ethics and social responsibility aim at setting boundaries for the sake of all the human beings involved in the whole educational system.

Problems of the European Education System Addressed and Long Term Benefits for Society

Currently, many (funded and non-funded) LA initiatives are carried out throughout Europe. Typically, Analytics have been developed and are provided for a specific stakeholder group, like students or teachers of a university. For instance, teachers are equipped with dashboards that show indicators and diagrams concerning the learning progress of their students. Similarly a LA solution could present such indicators to students, e.g. to make them aware of their performance in comparison to peers. In some cases the exploitation of technology usage data lacks the consideration of ethical issues, for instance if students are not aware that and how their data is being used by LA facilities. This is particularly the case if the institution analyzes technology usage data in order to identify at-risk students, which has been reported by single universities. Against this background, this GCP can enhance LA-related projects in different ways.

Above and beyond it should broaden the view on LA, particularly concerning the stakeholder groups. As can be observed in various research projects, Analytics often addressed one specific target group, precisely workplace learners (e.g., MIRROR), young children (e.g. eCUTE or MIROR), adult learners (e.g. ImREAL), lifelong learners (e.g. ROLE or GRAPPLE), learners in general (e.g. ALICE or TARGET), game-based learners (e.g. 80 Days or SCY), collaborating groups of learners (e.g. idSPACE or Metafore), and so forth. Although some approaches consider other stakeholders, like teachers or the organization, these projects either are not addressing Analytics or not all involved target groups and their responsibilities.

Additionally, the GCP deals with ethical issues concerning LA. Such concerns have been elaborated on a theoretical level e.g. by Slade and Prinsloo (2013) but lack practical experiences. In the scope of EU projects, aspects like privacy management have been tackled in various projects, like workplace learning (e.g., APOSDLE) or lifelong learning (e.g. ROLE) but have approached sustainable solutions or experiences based on large data sets. Finally, human responsibilities of LA—e.g., the protection of humans' privacy or other ethically issues restricting a fully open Analytics process—have not been addressed in a holistic way in any research initiative so far.

Main Activities to Address the Grand Challenge Problem

The core activities of this GCP comprise the following tasks.

- **Extending the 'target' of Analytics to all stakeholders**: Instead of restricting a LA approach to learners and teachers, all involved stakeholders should be considered for all phases of Analytics, e.g. also for monitoring. Hereby the ultimate goal is that the analysts themselves are target of Analytics.

- **Developing a (non-invasive) method to evolve actors to analysts**: Learners as well as all other stakeholders should get an overview of LA and its benefits, and understand their role in the Analytics Process. Through an Analytics-like approach, each actor should be motivated to develop competencies for analyzing and improving learning.
- **Empowering actors**: By considering the interdependence of analysis feedback on decisions and power relations, end-users should be empowered to make use of LA solutions.
- **Making human responsibility explicit**: Contrary to many LA initiatives, this GCP considers making human responsibilities explicit for all stakeholder groups.
- **Supporting reflection and openness in professional behaviors and attitudes**: Going beyond the goal of fostering reflection through Analytics, the openness in learning behavior and attitudes is considered an important aspect of this GCP. As mentioned before, restrictions for Analytics are given through ethical issues, while indicators and visual elements must be simple and understandable and their generation must be reproducible.

On a pragmatic level, two scenarios are considered to be of relevance for this GCP. On the one hand, risk prediction can be seen as an enabler for opportunity management. Risks comprise aspects like the possibility to drop out of a study due to a weak performance, low quality of learning materials, or even more critical flaws in a study program. On the other hand, the nurturing of excellence might be of relevance for career considerations of learners. This GCP can be seen as one possibility to identify and foster strengths of students, which is a crucial issue e.g. due to the massification and standardization of higher education study programs (cf. Johnson et al. 2012). Thus, the following technical challenges can be highlighted as a consequence of this GCP:

- **Combination of risk indicators with opportunity recommendations** in an interactive LA process—for example, technology usage data can be used to identify at-risk students so that teachers (or the LA solution) can intervene and avoid dropouts in their courses.
- Development of **adequate and non-manipulative (!) visualization**—diagrams and other visualization techniques often tend to manipulate the perception of humans. In many cases, pure numbers can be seen as a neutral and efficient way to give specific feedback to a stakeholder group.
- Support of **data collection and analysis** (a) under the **consideration of ethical issues** like privacy and (b) **by easily available services** (e.g., from the cloud)—ethics requires restrictions from a LA solution, e.g. to preserver users' privacy or avoid self-exploitation of humans. On the other hand, the heterogeneity and distribution of educational software tools increase the vulnerability of the educational setting. Consequently, services from the cloud must be reliable, mature, and fast in order to be applied for learning and teaching.
- Exploitation of **machine learning techniques to predict risks and opportunities** that can serve as a valuable input for sense-making—examples from the

scientific community comprise methods to predict the performance of students in courses or in collaborative activities, machine learning based approaches to analyze data and provide dashboards with relevant information for students and teachers, etc.

Timeframe for the Grand Challenge Problem

The timeframe for implementing the GCP ranges from 5 to 7 years, depending on the application scenarios to address and the broadness to roll out prototypic solutions to evaluate the validity of the Grande Challenge.

Measurable Progress and Success Indicators

Similarly to evaluation strategies for Knowledge Management initiatives (cf. Dalkir 2011), progress and success of this GCP is measurable on different levels and through different indicators. In the following, the three levels for measuring the success of the GCP are explained, and sample performance indicators are highlighted:

- On a micro level, it is possible to define **indicators being related to courses**, e.g. the efforts to be spent in a course and the actual efforts, tasks to be accomplished, time spent on tasks, etc. Moreover, risk indicators and opportunity recommendations for individual students, teachers, and other stakeholders in the learning process can be evaluated with respect to factors like the (perceived) accuracy, the usefulness, coverage, novelty, etc. On this level, valuable insights into students' performance (e.g., the risk for failing in the final exam or inactivity for longer time periods) and the quality of courses (e.g., flaws in materials or the didactical design of courses) can be gained.
- On a meso level, this GCP allows assessing **improvements within an organization**. Thus, the (hopefully positive) impact on people (i.e., students, teachers, policy makers, etc.), on processes, on products (e.g. consulting services for the industry), or on the organizational performance per se can be measured through traditional indicators which are well established, e.g. in the field of Knowledge Management (see Dalkir 2011).
- On the macro level, this GCP also enables **measuring the improvement of study programs or higher education organizations** and comparing them to each other. Beside learning-relevant indicators, such measurements should include financial aspects or feedback on graduates, e.g. from industry. The timeframe for these success indicators, however, exceeds the before-mentioned 7 years.

Attraction of Funding

Funding can be attracted through traditional research initiatives, such as national or European funding schemes, or through cooperation with industry, primarily from the educational sector.

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Grand Challenge Problem 9: How Can TEL Contribute to Challenging Educational Inequalities?

Helen Beetham, Carlo Perrotta and Debbie Holley

Abstract Access to educational opportunity is undoubtedly extended by the availability of open learning materials, learning communities and forms of open accreditation. However, there is limited evidence that access to these digital opportunities translates into educational success for those without other forms of educational, social and cultural capital. This Grand Challenge calls for a research agenda with two broad goals:

- to identify and ameliorate the role TEL plays in various systemic inequalities we identify;
- to identify and support responses on the part of educational organisations and actors that redress inequalities of educational participation and outcome.

Keywords Equality · Opportunity · Accessibility · Cultural capital · Digital capital · TEL

Access to educational opportunity is undoubtedly extended by the availability of open learning materials, learning communities and forms of open accreditation. However, there is limited evidence that access to these digital opportunities translates into educational success for those without other forms of educational, social and cultural capital (Bach et al. 2013). Unequal distribution of digital access and

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know-how has in fact introduced new inequalities of participation and of educational outcome (Wessels 2013; Zillien and Marr 2013).

Beyond individual cases, the open digital landscape favours globally successful institutions and puts pressure on the local languages, practices and education systems that are most able to support those currently disadvantaged (Olaniran and Agnello 2008; Marginson and Ordorika 2010). The TEL project in Europe has coincided with the growth of technicist, managerial and commercialised approaches to education (e.g. Noble 2003) which have weakened the historical commitment to education as an emancipatory project and a democratic right. For example, business models for digital provision favour mass instruction via online resources over contextualised, participative or negotiated learning.

This Grand Challenge calls for a research agenda that can address some of these trends. It will have two broad goals:

- to identify and ameliorate the role TEL plays in the systemic inequalities we have identified;
- to identify and support responses on the part of educational organisations and actors that redress inequalities of educational participation and outcome.

Problems of the European Education System Addressed and Long Term Benefits for Society

Some problems currently endemic to education in Europe pertain closely to the role of technology, for example the crisis in the 'value offer' of traditional higher education in the face of low-cost digital alternatives. While the collapse in public funding has well-known causes, the response of many institutions—to seek alternative markets via digital branding, or use digital media to provide more massive and distributed courses—is creating problems of its own. One is stratification, with TEL being used to offer cheaper, less intensively supported, less humanly rich (and less educationally successful) experiences to those already educationally disadvantaged. Another is dehumanisation. Advances in learner tracking and analytics, in standardised testing and accreditation, and in forms of automated tutoring can all be used to support excellent teaching but they have also contributed to the dehumanisation of learning relationships and to the individualisation and commodification of the educational experience.

In general terms, a lack of access to positive educational outcomes is producing generation of young people lacking relevant experience and skills (see UNESCO 2012).

Our research agenda puts technology at the service of citizenship, social participation and equality of outcome. Specific benefits will include:

- a framework which TEL funders, strategists and policy-makers can use to help identify the causes and consequences of inequalities;
- exemplary TEL responses which enhance equality of participation and outcomes;
- interventions which strengthen the democratic and socially cohesive functions of education.

Main Activities to Address the Grand Challenge Problem

We propose a number of activity areas, with more areas to be identified through scoping and iterative synthesis of results. Each activity area will undertake:

- problem definition: review research and policy literature for evidence of 'equality gaps' and potential responses at the conjunction of education and technology;
- research methods: model an egalitarian, empowering, participative approach;
- impact: define how deliverables will enable relevant actors to redress inequalities, engage those typically excluded and foresee long-term equality impacts of their actions;
- data collection, analysis and review;
- public engagement: communicate outcomes beyond the TEL research community, engaging civil society and a range of educational actors.

Proposed activity areas for research funding will initially include:

- Open education: analyse inequalities of access and educational success/outcome in an open educational environment: develop and test explanatory models.
- Digital capital/capability: examine what is meant by digital capital or capability (with reference to the European DIGCOMP project), gather evidence of its distribution within and across European populations and explore the consequences for educational outcomes.
- Informal, local/contextual and marginal learning cultures: explore how these learning cultures are expressed and enacted in digital spaces, and what new challenges they face in a globalised education system; provide a range of relevant pedagogical models.
- Design research: enquire how citizens and groups use digital resources to support educational and other forms of cultural/social success; produce model design approaches that take full account of cultural, social and geographical differences.
- Disenfranchised/disengaged young people (18–24 years) in the European community: explore models for engaging young people in educational communities and opportunities that meet their real life needs, with digital technologies as enablers.

Timeframe for the Grand Challenge Problem

Define problem, engage stakeholders with research, collect and analyse data—1–2 years.

- Develop conclusions, produce relevant models (conceptual and explanatory models, design approaches, pedagogical models and policy/practice recommendations) in partnership with stakeholders, engage stakeholders with outcomes—2–3 years.
- Embed, evaluate impact, verify models, produce exemplars and case studies—3–5 years.

Measurable Progress and Success Indicators

At the research stage, we expect to see milestones and indicators such as ethical clearance, evidence of stakeholder engagement, open data sets, peer-reviewed research publications/presentations and a sustainable research network/community emerging. At the problem definition stage, we expect models and approaches to be piloted with key stakeholders and user communities, with evidence of engagement and use. At the impact stage, we will require evaluation/impact reports, final/verified versions of models, exemplars and case studies available in sustainable form, recommendations accepted by stakeholder bodies contributing to changes in practice/policy, and peer-reviewed publications.

Attraction of Funding

Our network is broad, inclusive and international. We prioritise democratic decision-making, open scholarship and sharing of ideas as the core values underpinning our work. Having identified ESRC (UK) and Horizon 2020 (EU) as suitable funders, we are currently exploring opportunities with Charitable Foundations interested in intercultural and transferable models of engaging disadvantaged youth across the USA/EU/Africa. Harnessing our common interests in democratic process, we envisage a digital and community-focused e-democracy project, with disadvantaged people involved as key actors. Applications will be framed to enable those from less advantaged economies to participate.

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Grand Challenge Problem 10: TELEARC an Agile and Productive Networking of TEL Small and Medium Sized Research Labs

Lone Dirckinck-Holmfeld, Nicolas Balacheff, Rosa Maria Bottino, Daniel Burgos, Angelique Dimitracopoulou, Sten Ludvigsen and Alain Mille

Abstract Small and medium sized research labs (SMLs) are dominating European TEL research. This is justified by the great numbers of countries and regions in Europe needing to develop a research and innovation competence to facilitate the diverse educational systems contextualized in various institutional settings across Europe. However, to strengthen the various research practices and to develop a common scientific language on TEL research the Grand Challenge

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Problem is to establish a vivid network and a community of practice among the research labs. TELEARC (Technology Enhanced Learning European Advanced Research Consortium) has been established to realize such a network. The chapter presents the framework of TELEARC.

Keywords Grand challenge · Technology-enhanced learning · Networked community · Infrastructure for learning

Most big players in TEL research are not located in Europe, although there is a long and vigorous educational research tradition. One of the challenges, but also a strength is that Europe is dominated by small and medium sized research labs (SMLs) within TEL research. This is justified by the great numbers of countries and regions in Europe needing to develop a research and innovation competence to facilitate the diverse educational systems, which are culturally, politically and economically diverse and contextualized in various institutional settings across Europe.

In order to bring European TEL research at the forefront, to strengthen the insights of the various research practices and to develop a common language between the different actors in Europe, the Grand Challenge Problem is to establish a vivid network and a community of practice, which can support in building up the research capacity, integrate better the research labs, align and synthesize the research findings.

Problems of the European Education System Addressed and Long Term Benefits for Society

The educational systems in Europe have been governed by different policies and priorities. The approaches to ICT are different and not always supporting learning in meaningful ways. Much implementation of ICT has taken place without systematic research and without linking research and educational practices.

TEL is a dynamic area with new technologies and learning principles, which raises new research questions. The area therefore needs an on-going focus on research and the translation of research into practice. Due to the relative huge investments local, national and international decision makers, agencies and leaders of educational institutions moreover demand research-based knowledge to back up political decisions.

Main Activities to Address the Grand Challenge Problem

In order to address this grand challenge at a European level, we propose to build an agile knowledge infrastructure based on the SMLs, which have TEL as their main research field.

A core issue is the dualistic relation between participation and reification integrating researchers from different traditions, educational, psychological, social and tech-research. Meaning is created through participation and active involvement, while reification is a matter of institutionalizing and accumulating the knowledge of the practice. In order for SMLs to engage in building the knowledge network, it should be meaningful.

Table 1 presents a first picture of the needs and offers, based on an exploratory analysis of SMLs, and the lessons learned from previous NoE (Kaleidoscope and STELLARnet).

A framework is offered by TELEARC (Technology Enhanced Learning European Advanced Research Consortium) established in 2009 with the mission to keep on the legacy of Kaleidoscope NoE. Kaleidoscope united more than 60

Table 1 Needs and offers of a TEL knowledge infrastructure

SMLs needs	Knowledge infrastructure offers
Visibility	• Unique portal • Presentation of labs and competences, • Links to services
Research capacity building • Complementary competence • Agile construction of consortium for calls • Need for a critical mass of expertise and minds • In-depth exchange on hot topics • Analysis tools, protocols and sharing data	• Easy access to other labs and a culture of collaboration (complementary competences, setting up consortia, finding expertise and minds) • Community building activities [hot seats, featured conferences and journals (stamps)] • TEL thesaurus and dictionary • Advanced seminars: Alpine Rendez-Vous • PhD collaboration and network for young researchers
Services • Identifying the best texts or conferences (article, report) on research issues • Accelerate the writing culture through feedback and benefiting of felicity conditions	• News-list • TeLearn enhanced with a flagging tool and possible comments • PhD writing week (retreat to think and advance writing, presentation of early writings and get feedback, presence of senior researchers)
Innovation and interaction • Influence decision makers view of priorities • Integration of TEL in the calls for the Grand Challenge (Horizon 2020) • Translate research findings to the practitioners community • Participation in innovation consortia on TEL	• Systematic work on GCP through lobbying and publishing • Publishing of an advice paper/meta paper about a certain theme as an outcome of the Alpine Rendez-Vous • High-level Business-School-Research-Governance roundtables (EU-level) in relation to the release of advice papers, and participation in innovation consortia

European research labs of small and medium-size, and is the first example of a network of SMLs. All together 1000 researchers were engaged in Kaleidoscope bringing the TEL research forward in Europe and internationally.

Timeframe for the Grand Challenge Problem

Building a knowledge infrastructure for SMLs is an ongoing process. Kaleidoscope (2004–2008) and STELLARnet (2009–2013) established a strong basis fostering the development of a learning community. These infrastructure activities have been carried on in different forums and will be expanded in the TELEARC SMLs agile and productive knowledge infrastructure.

Measurable Progress and Success Indicators

The progress and success of the knowledge infrastructure is to establish linkages between the labs and to do better and more qualified research. Below, we have selected a number of tangible progress and success indicators:

- Number of SMLs: 10 by March 2014, 40 by March 2015
- Coverage of Europe: a great majority of regions
- Development and use of services (content, statistics)
- Number of submitted collaborative projects (successful and not successful), co-authorship, bilateral agreements, co-produced journal articles
- Alpine Rendez-Vous, GCP book
- Marie Curie grant, PhD network, PhD writing week
- Infrastructure grant (ESFRI) or other EU grant
- Co-organiser of High-level Business-School-Research-Governance roundtables (EU-level)

Attraction of Funding

One of the key-support to this GCP will come first from the SMLs themselves and their capacity to voluntarily build relationship. Other funding will come from projects and activities where TELEARC will be a partner. For some basic activities, TELEARC will be the leading body.

In order to build an agile and productive network of SMLs TELEARC is drawing on different sources for funding:

- TELEARC fee
- European Commission, different instruments in different directorates (the European Strategy Forum on Research Infrastructures (ESFRI), Information Society and Media, Marie Curie Actions).
- National and Regional support (e.g. GDRI in France, Digital Humanities in DK)

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Grand Challenge Problem 11: Empowering Teachers with Student Data

Barbara Wasson, Cecilie Hanson and Yishay Mor

Abstract Technology-rich learning environments generate rich streams of data pertaining to students' and teachers' actions and their outcomes. This data can be harnessed and used by teachers to monitor and improve their practice, but new methods and tools are needed that (1) help teachers to harness and interpret this data, and subsequently, (2) incorporate it into a framework of continuous professional development. Approaches and methods from teacher inquiry into student learning (TISL), learning design (LD) and learning analytics (LA) can be combined to support a teacher-led design inquiry of learning and innovation cycle. A transdisciplinary approach, which draws on insights from epistemic practice, pedagogical practice, design inquiry of learning, teacher inquiry, e-assessment, and learning and teaching analytics and visualisation, will produce methods and tools to enable teachers to reflect on their own teaching and student learning in order to improve teaching practice.

Keywords Learning design · Teacher inquiry into student learning · Learning analytics

Today's technology-rich learning environments generate rich streams of data pertaining to students' and teachers' actions and their outcomes. This data can be harnessed by teachers to monitor and improve their practice, but new methods and

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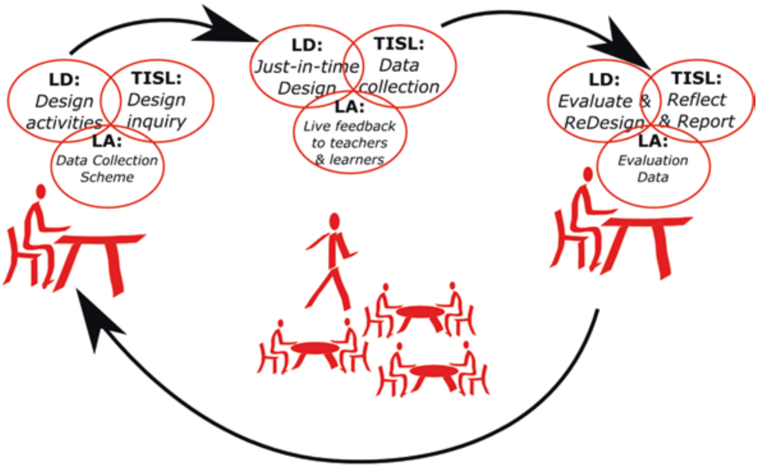

Fig. 1 Teacher-led design inquiry of learning and innovation cycle

tools are needed that (1) help teachers to harness and interpret this data, and subsequently, (2) incorporate it into a framework of continuous professional development. Approaches and methods from teacher inquiry into student learning (TISL), learning design (LD) and learning analytics (LA) can be combined to support a teacher-led design inquiry of learning and innovation cycle (Fig. 1). A transdisciplinary approach, that draws on insights from epistemic practice, pedagogical practice, design inquiry of learning, teacher inquiry, e-assessment, and learning and teaching analytics and visualisation, will produce methods and tools to enable teachers to reflect on their own teaching and student learning in order to improve teaching practice. The result is an accumulation of knowledge about teaching by investigating education as a value driven, evidence supported, and innovative practice.

Problems of the European Education System Addressed, and Long Term Benefits for Society

The 2012 Rethinking Education communication from the European Commission highlights two priorities that are particularly relevant for this GCP: Scale up the use of ICT-supported learning and access to high-quality Open Educational Resources, and Revise and strengthen the professional profile of all teaching professions. The first priority will result in the availability of even more easily accessible student data, but how can it best be used? In particular, how can it be used to address the second priority and strengthen the profile of the teaching profession?

The long-term benefit for society will be a workforce of empowered teachers with the methods and tools available to reflect on and improve their own practice and student learning; thus making the teaching profession more attractive and improving the working life of teachers.

Main Activities to Address the Grand Challenge Problem

The GCP will involve basic research that focuses on understanding how to support the professional practice of teaching with methods and tools to empower pedagogical decision-making. This involves a range of activities including:

- Defining a model of, and tools to support, Design Inquiry of Learning that embodies scientific standards and yet is accessible for practitioners
- Developing methods for aggregating outputs from teachers' design inquiry of learning to create a robust canon of evidenced design knowledge in education.
- Investigating, with teachers, how to design learning and assessment activities based on student data
- Developing methods and tools for capturing process and product aspects of student learning and assessment
- Developing tools, toolkits and services, which support the use of data to make good pedagogical decisions, both in real-time and retrospectively
- Creating better learning and teaching analytics methods, tools and open standards
- Conducting wide-scale development, evaluation and implementation of new teaching practices, which embody LD and teacher inquiry as core elements
- Identifying new competences for teachers in using evidence-based student data in teacher-led design inquiry of learning and innovation
- Developing professional training mechanisms to guide teachers in adopting a design inquiry stance
- Develop methods to scale up successes
- Addressing policy makers and school leaders about the importance of using student data to improve learning, and hence school development, and the implications of this for the working life of teachers

Timeframe for the Grand Challenge Problem

The timeframe is about 5–10 years. The development of data collection methods and processing tools (e.g., Romero and Ventura 2007; Kickmeier-Rust and Albert 2012; Bull et al. 2012) and support for data usage through, for example, LA (Ferguson 2012) and teaching analytics (Vatrapu et al. 2012) has begun. Learning design is establishing itself as a promising field of research and practice (Mor et al. 2013). Specialised conferences and workshops are emerging; special issues in journals address these issues, and projects are being funded (e.g., EU's NEXT-TELL and Metis Projects).

Measurable Progress and Success Indicators

- A repertoire of new methods and tools to support teacher-led inquiry into student learning
- Recognition of the value of evidence from student data to support pedagogical-decision making evidenced by the adoption of methods and tools by teachers and school leaders
- Changed role of assessment from summative evaluation to an integrated formative assessment practice support by student data
- A more attractive teaching profession evidenced by increased interest in, and decreased drop-out rates from the profession, and an increased motivation among practitioners to change their practice
- Recognition by policy makers, public media and school leaders of teaching as an inquiry practice, and consequently the need to provide teachers with the resources for conducting inquiry.

Attraction of Funding

The European Research Council and National Research Councils to fund the basic research, and eventually commercial actors as methods and tools are proven promising.

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Grand Challenge Problem 12: Assessing Student Learning Through Continuous Collection and Interpretation of Temporal Performance Data

Inge Molenaar and Alyssa Wise

Abstract Learning and assessment have traditionally occurred as distinct activities, where engaging in one takes time away from the other. This grand challenge explores how advances in data collection and analysis can be leveraged to integrate learning and assessment in one single process. Developing assessment during learning within technology enhanced learning systems requires understanding the temporal characteristics of learning: what are meaningful data traces, how do these develop over time, and how teachers can best be informed of learners' progress. The challenge is met when these measures and methods are adopted by educators as a viable alternative to traditional testing.

Keywords Assessment · Learning analytics · Educational technologies

Assessment is a critical and powerful component of all educational systems and important role of all teachers. Serving both summative and formative purposes, assessment activities account for an extensive portion of classroom time. This grand challenge addresses the classic dilemma faced by teachers—to teach or to test—by integrating learning and assessment in a single process.

Advances in data collection and analysis technologies present the possibility to track and interpret the traces students naturally leave behind while learning as evidence of their development over time. This approach aligns with well-established philosophical conceptions of learning as a process that unfolds over time,

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appraising the evolution of student performance and understanding as part of the activity of learning itself. The grand challenge, then, is to develop specific processes and techniques that teachers can use in conjunction with classroom activities to generate information that is useful in both documenting learning gains and determining future learning activities.

Problems of the European Education System Addressed and Long Term Benefits for Society

Current assessment practices are driven by the need to evaluate student's progress and to benchmark educational effectiveness in schools. Yet when assessment takes the form of (high-stakes, standardized) testing it is divorced from learning processes. Also, if the tests used are inauthentic assessments of desired student knowledge and skills, then learning activities may be distorted to align with the tests. The main problem this Grand Challenge addresses is the lack of robust assessment schemes that provide valid and useful information about student learning over time without sacrificing learning time for testing time.

Main Activities to Address the Grand Challenge Problem

To address the Grand Challenge, we need to gain deep understanding of the temporal characteristics that indicate learning (operationalized as the development of knowledge, skills, attitudes, competencies, and dispositions).

- First, there are important issues related to the question of what should be measured, i.e. determining what constitutes meaningful traces for teachers that indicate learning providing valid and useful information about students' progress and development.
- Second, on a conceptual level, we need to advance understandings of how learning processes unfold over time, how indices of learning develop temporally (e.g. patterns of growth/decay, disruption of prior ways of thinking to develop new ones), and what different emerging methods can tell us about how learning progresses and develops over time.
- Third, we need to develop tools that facilitate the collection of such meaningful data and its productive analysis and interpretation for real-time formative and summative assessment in classrooms.

Importantly, each of these areas needs to be explored in consultation with classroom teachers such that the final results are processes and techniques that are useful to teachers and easily integrated into existing classroom routines.

Timeframe for the Grand Challenge Problem

The timeframe for this grand challenge is 5 years. First, researchers and teachers collaboratively need to determine which temporal data to collect, how to analyze them with a variety of analysis methods, and how to interpret these data. Second, selected methods are examined within educational institutions to assess their practical value, validity, and reliability.

Measurable Progress and Success Indicators

Progress on this grand challenge will be measured by the usefulness of the temporal characteristics and analysis techniques developed as indicators of the development of knowledge, performance, skills, and competences. The long term proof of concept is that these measures and methods are formulated in ways that can be easily used by educators and are adopted by instructors as a viable alternative to traditional testing. These temporal characteristics should be able to both document (explain) students' ongoing development and be useful to tune instruction to the individual needs of the students.

Attraction of Funding

Addressing this grand challenge demands for international collaboration between researchers from multiple backgrounds (Computer Science, Psychology, Educational Sciences, Mathematics, and Statistics) and frontline teachers in educational institutions. Funding should therefore ideally come from an international funding body, for example, the European Union or from collaborations between national funding agencies, such as the Open Research Area or different ministries of education that allow for international research collaboration. Another route could be a collaboration between ministries of education of multiple countries. Assessment is an expensive time-consuming process which it makes in the interest of educational institutions and national government to progress on this grand challenge.

A Challenge to Enhance the System of Education—a Comment from a Researcher Perspective

Mike Sharples

Abstract Technology-enhanced learning is a complex dynamic system of technologies and practices, informed by pedagogy. Aspects of this system are very difficult to change because they are bound together in an interlocking set of curricula, standards and examining processes. Thus, an overarching Grand Challenge is for educational institutions to break this deadlock and become learning systems, with educational technology as the mechanism for institutional development as well as for enhancing learning. This creates a productive cycle where analyses of current practices, using learning analytics, inform objectives and strategies that are put into practice through a process of technology-enhanced learning design.

Technology and Educational Transformation

Technology-enhanced learning is a complex system that consists of much more than a set of research-informed products (TELRP 2013). It encompasses a dynamic interaction between communities, technologies and practices, informed by pedagogy. Some aspects of this dynamic system are very difficult to change because they are bound together in a mutually reinforcing mesh. Formal education consists of an interlocking set of curricula, standards, examining processes and teaching practices that are very difficult to shift. Similarly, commercial educational publishing of textbooks and journals has been slow to respond to external pressures for interactive media publishing and open access.

For the past hundred years, grand predictions have been made about the future of education. Looking back, they appear to overstate greatly the power of

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technology to change this super-stable system. In a magazine article published in 1913 Thomas Edison was quoted as saying “Books will soon be obsolete in the public schools. … It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed inside of ten years.” Over the succeeding decades similar predictions have been made about the transformative power of educational television in the 1960s, language labs in the 1970s, computer-based instruction in the 1980s, integrated learning systems in the 1990s, virtual worlds for learning in the 2000s and Massive Open Online Courses (MOOCs) in the 2010s.

It seems clear that no injection of technology alone will transform education, in the way that a driverless car may transform road transport. So what should be the grand challenges for TEL? Arguably, the nearest to transformative technologies for learning to date have been flipped learning (Hamden et al. 2013) and the MOOC. Neither of these arose from a Grand Challenge or a major research programme, but rather they emerged from individual initiatives (by Salman Khan, Dave Cormier, George Siemens and Stephen Downes, the latter three inspired by the Open Educational Resources movement). Flipped classrooms and MOOCs are both combinations of technology and pedagogy, they bridge the gap between formal and informal settings for learning, and they address the affective aspects of learning, motivating people to learn through attractive media and inspiring teaching. They also have broad applicability across ages and sectors, their reach is global and, most important, they do not seek the permission and purchasing power of formal education.

Smart Cities

Taking these aspects as indicators of possible success (combining technology and pedagogy, bridging formal and informal settings, addressing affective aspects of learning, broad applicability and ability to grow outside the formal education sector), how do the Grand Challenge Problems measure up? Perhaps the closest match to these criteria is in the GCP1 Smart City Learning challenge. The opportunity here is to extend a city infrastructure to enable learning. Just as cities are places for living, working, shopping and travelling, so they can be sites for learning. To some extent they already are, but the learning has tended to be confined to specific locations (libraries, museums, galleries) or to learning about the city itself through information boards and signage. The opportunity is to extend the city as a site for learning: about its inhabitants, its structure, its history, and about the fabric and dynamics of cities in general. Major tourist destinations such as London and Florence are obvious candidates. The Streetmuseum smartphone app by the Museum of London provides an augmented reality tour of the streets of the city, with the ability to hold the camera up to a present-day street scene and see how it looked in the past, accompanied by information about historical events.[1]

But as the grand challenge indicates, all cities could become "inclusive and supportive of the whole complexity of human learning". Just as many bus and tram stops offer dynamic information about the next arrival, so buildings could inform about their energy usage, or streets about their levels of carbon monoxide and other pollutants. Residents in a city could create stories, trails and language resources for visitors. Art and culture can be taken onto the city streets through augmented reality graffiti. The learning can be enabled by self-directed interaction with resources in situ, by enhancing meaning-making through annotation of places and artefacts, by making connections between people in actual locations and online ones and by creating storytelling trails that lead visitors and new residents through enriched paths around a city. The challenge is how to make this work in a way that informs, enlightens and inspires, creating a greater affinity with the living city, not just a new electronic cacophony of city noises and images.

Connecting Learning in Formal and Informal Settings

Other Grand Challenge Problems explore the connections between learning in formal and informal settings. The GCP5 and GCP6 grand challenges envisage vocational education students as 'connectivist' learners, bridging the divide between the workplace as a site for acquiring procedural knowledge and skills, and the classroom as a place for sharing and reflecting on situated experience and for refining skills. For this to happen, schools in the vocational education and training (VET) sector must be more tightly connected to the world of work. Technology can assist by allowing learners to capture workplace incidents as video clips, to explore simulations of their real work settings and to take their reflective practice back into the workplace through mobile devices. In the Dual-T project Motta and colleagues (2014) equipped apprentice cooks, pastry cooks and car mechanics with headband cameras or smartphones to capture workplace incidents on video that provided resources for discussion in the classroom. They conclude: "Capturing visual materials through mobile devices on activities experienced at the workplace and using them at school to promote specific learning activities can constitute an effective way to give apprentices the chance to learn and reflect on their own professional background" (Motta et al. 2014, p. 176).

But for this to happen on a large scale, teachers need to extend their practices to embrace not only the new technologies but also the new connections to the workplace that these enable. As GCP5 indicates "schools must be reorganized as a learning community that shares and connects experience among itself

[1]See http://www.museumoflondon.org.uk/Resources/app/you-are-here-app/home.html.

and with the workplace". However admirable the aspiration, it is unlikely to be realised, at least in the short term, within the constraints of current vocational education. There are no incentives within the current overstretched system for teachers and learners to share experiences or to exploit technology to connect with workplaces. Perhaps the best hope for the future lies in new industry–education partnerships, such as the University Technical Colleges in the UK that offer partnerships with companies to undertake project-based vocational learning enriched by technology.

Technology-Enhanced Science Inquiry

A similar systemic resistance to change is faced by attempts to empower science teachers with technology-enhanced scaffolding to improve inquiry learning (GCP3). The curriculum may require students to understand science inquiry, and individual teachers may be inspired to adopt inquiry methods for science education. But factors including timetabling, health and safety regulations, lack of equipment and a reluctance to allow students to use their own smartphone devices as tools for data capture mean that it is difficult, if not impossible, to enact a full cycle of inquiry-based learning within the classroom. There are opportunities to extend inquiry learning beyond the classroom, with the teacher and students deciding an inquiry question in class, then the students using mobile devices to collect data at home or outdoors, and then sharing and presenting the results back in class (Anastopoulou et al. 2012). However, this requires a teacher who not only understands the methods and practices of 'extended inquiry learning', but is also capable of managing the disciplined improvisation needed for a classroom lesson to integrate the data collected by 20 or more learners on mobile devices, and bring the inquiry process to a satisfying conclusion.

Providing a teacher with a 'virtual assistant' (GCP3) to analyse and respond to individual learners may seem like a means to address this problem by reducing the burden of classroom management. But this raises a classic problem of artificial intelligence for the real world. The nature of genuine scientific inquiry is that it may produce unpredictable findings, so either the inquiry activity must be constrained to fit the limitations of the virtual teaching assistant, providing simulated results within narrow parameters, or the human teacher will need not only to manage a class of human students but also to interact with a virtual assistant when it fails to cope with the complexities of real data, and explain its limitations to the students. Injecting virtual teachers into real classrooms is likely to increase, not reduce, the complexity of science teaching.

Learning Analytics

An alternative approach to virtual assistance is to empower the human teacher to make appropriate decisions, based on rich data about student learning, whether that occurs within the classroom, outside it or online (GCP4, GCP7, GCP8, GCP11, GCP12). This approach of providing 'teacher dashboards' of real-time information about learners' knowledge, activity and emotion has much appeal as a grand challenge. It attempts to empower rather than replace the teacher. It is based on a theory and practice of visible learning that is shown to be effective in improving learning outcomes (Hattie 2009). It recognises the real or online classroom as a site of complex cognitive, social and emotional interactions. And it can be extended to a large scale—for example, the STEMscopes online science curriculum can provide visualisations of the activity of 50,000 teachers and over a million students.[2] The most effective approaches so far are beguilingly simple. The Purdue Signals system (Pistilli and Arnold 2010) provides an early warning system of problems with a course or with individual students by automated analysis of performance data into a 'traffic light' visualisation. A green signal shows that the work is progressing smoothly, amber indicates areas of concern and red flags up significant problems. These signals can be shown to the teacher or to students, and the teacher can intervene by contacting students at risk of failure to offer support. Analysis of outcomes for courses that have used the Signals system shows a consistently higher level of exam grades (Pistilli and Arnold 2010).

So, analytics for learning can work. The irony is that it does so by reducing the dynamic complexity of learning to three colours: green, amber, red. But that apparently reductive simplicity belies the sophistication of the approach. It can provide similar information to both teacher and students, leading to a convergence of understanding and goals for improvement. It can be applied dynamically, providing timely feedback on performance. It can reveal problems with a course, with groups of students or with the performance of individual learners. And it can provide a basis for action, by identifying a source of difficulty and an opportunity for focused teacher intervention.

We should also be aware of the limitations of this approach, since analytics is not a panacea: it is no substitute for an inadequate curriculum or weak teaching. A dashboard can only reveal what can be measured. Currently, this is largely based on when the student has completed an activity, such as viewing a page of online material or contributing to a forum, or has taken a test.

A grand challenge is to extend this to other kinds of learning and interaction, such as self-regulated experiential learning in groups (GCP2). The signals from learners could include facial expression, speech patterns, eye movement and physiological data such as heart rate. There may be a temptation to dismiss this emotional data as pseudo-science: measuring how much children fidget as an indicator

[2] http://stemscopes.com.

of their boredom. But emotional self-regulation based on bio-feedback from heart rate and skin conductivity has been shown to help financial traders improve their decision-making—particularly, in addressing a key problem known as the 'disposition effect' whereby investors in a volatile trading market hold on to losing positions for longer than to winning positions (Peffer and O'Creevy 2012). Can similar methods be used to assist classroom or online learning by helping learners, individually or collectively, understand and manage their emotions?

For learning analytics to be extended across formal education does not require the wholesale reform of schools or universities, Indeed, a criticism levelled at learning analytics is that the collection and analysis of educational data reinforces traditional teaching practices and sustains inequalities, providing more opportunities for testing and number-crunching rather than innovations such as project-based learning that may be harder to measure. As GCP8 indicates, ethics and social responsibility should be at the core of learning analytics, not only in setting boundaries on what data should be collected, but also questioning whether data collection leads to greater accountability, or to teaching by numbers.

Where learning analytics can work well, is when the data can be visualised in ways that provide immediate feedback to learners on how they are progressing in relation to goals they have set themselves, to teachers on where to intervene and support, and to policy makers in exploring opportunities for re-designing education. These feedback loops then may enable an educational system that is dynamic as well as complex, working to achieve goals rather than stifling change, and empowering innovators not just satisfying administrators.

A Challenge to Create Dynamic and Innovative Systems of Education

Thus, an overarching challenge is to employ technology in ways that create dynamic and innovative systems of education, where teachers, learners and policy makers are enabled to explore new methods based on combinations of powerful theory and sound evidence. For this to happen educational institutions need to become learning systems, with educational technology as the mechanism for institutional development as well as for enhancing learning. We can picture this, in Fig. 1, in terms of the organizational double-loop learning of Argyris and Schön (1974, 1978).

An effective learning organisation is not only able to adjust to changes in the external or internal environment, but also to reflect on the process of change and thus change its objectives and strategies to enable more effective working. The system of education now has both the methods and the technologies to put this into practice. Innovations in pedagogy (Sharples et al. 2014) and studies of the relation between learning theories and effective practices (e.g. Hattie 2009) can provide guides to theory-informed educational innovation. These can inform

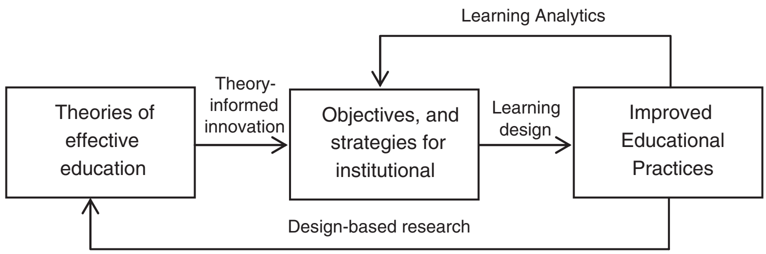

Fig. 1 Double-loop organisational learning for educational change

a productive cycle where analyses of current practices, using learning analytics, provide grounds for changed objectives and strategies that are put into practice through a process of technology-enhanced learning design. The larger cycle of organizational change comes through a process of design-based research where "insights from many different fields are converging to create a new science of learning that may transform educational practice" (Meltzoff et al. 2009).

MOOCs are the new proving ground for this organisational double-loop learning. They offer what was previously missing from an effective learning system: the ability to carry out research based on rapid cycles of learning design and analyses of large-scale data, leading to development of new theories of effective online education innovation, that inform further practice. As an example of the new science of learning in action, the FutureLearn platform (www.futurelearn.com) to support MOOCs from 50 partner institutions, is being developed by incremental Agile software methods (Rubin 2012). Each two-week cycle of development includes a 'pedagogy scrum' that sets objectives to develop major educational functions for the platform and proposes how to re-conceive the underpinning theories for massive-scale online learning. Data from learner activities on each course are continually analysed and fed into the pedagogy scrum to improve functioning of the platform. The data also informs research into the emergence of a new pedagogy of massive online social learning, explored by a research network of FutureLearn partners.

This iterative pedagogy-informed process of learning design is far removed from the typical process of educational technology innovation in schools, universities or workplaces, where "if there's any change it's very slow. I don't think the educational establishment has really embraced these ideas [of creative and collaborative learning]" (Resnick, cited in TELRP, 2013). The easiest and most commercially viable use of technology-enhanced learning is for it to reinforce traditional education by providing more efficient methods of teaching, tracking and testing. The alternative—to challenge educational inequalities (GCP9) by devising new forms of technology-enhanced learning that empower and emancipate—requires a "vivid network and community of practice" (GCP10) that coordinates research labs and schools capable of enacting large-scale, sustainable innovation. The network must itself adopt agile methods of research, implementation and dissemination, to experiment with new forms of learning for a digital world. The ultimate goal is a pan-European TEL network, similar in scope and ambition to those of particle physicists[3] or climate scientists,[4] which organises large-scale design research projects, provides an international forum to align efforts of thousands of learning technologists and educational practitioners, interprets findings from a wide variety of educational experiments within and beyond classrooms, and provides policy makers and education leaders with the best possible evidence of successful innovation.

The quest to improve education for all, enhanced by technology, is at least as important to society as finding the Higgs Boson and or investigating climate change. To coordinate this effort requires a shared vision and the collective exercise of ambition by researchers, practitioners and policy makers.

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[4]See http://www.wcrp-climate.org.

The Grand Challenge of Diversity—A Comment from a Researcher Perspective

Nicolas Balacheff

Abstract This new series of Grand Challenge Problems (GCPs) addresses cognitive as well as emotional issues, individual as well as societal issues, epistemic as well as ethical issues. This diversity is associated with a movement tending to blow up the borders between the cognitive and the social, the formal and the informal, the school and the workplace. But the newest and most remarkable fact is that this set of research propositions is at the same time on the edge of the disappearance of institutions as the unique site for teaching and learning, with an increasing emphasis on self-regulated learning and learning communities, and of the rise of technologies empowering institutions and teachers with more efficient tools and means to support, drive, and assess learning.

This new series of Grand Challenge Problems (GCPs) from the Alpine Rendez-Vous illustrates the multidimensional and eclectic character of research on Technology Enhanced Learning (TEL). Expressed in a condensed way with a vision of the future of TEL, they address cognitive as well as emotional issues, individual as well as societal issues, epistemic as well as ethical issues. This diversity is associated with a movement tending to blow up the borders between the cognitive and the social, the formal and the informal, the school and the workplace. But the newest and most remarkable fact is that this set of research propositions is at the same time on the edge of the disappearance of institutions as the unique site for teaching and learning, with an increasing emphasis on self-regulated learning and learning communities, and of the rise of technologies empowering institutions and teachers with more efficient tools and means to support, drive, and assess learning.

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This diversity witnesses the multiple pushes TEL research has to constantly take into account with the continuous renewal of technology, the advancement of cognitive sciences and especially neuroscience, and a rapidly growing market both in terms of infrastructure and innovation. Still, one can recognize across these GCPs, despite their diversity, that they share a common set of problems calling for more basic research effort on learning, teaching, and learning design.

From the Data Deluge to Learning-Aware Environments

"Data" is the keyword linking all the GCPs. In the first place it refers to data gathered from students' activity with the vision that new models and tools must be developed and used to empower teachers (GCP 11). This data comes essentially from tracing learners in the digital space, but it should also include gestures, emotional signals as well as contextual information. The flow of data is so strong and so diverse that making use and making sense of it is in itself a grand challenge that several propositions take up from their different perspectives. One direction, now classical, consists of providing feedback to learners with awareness indicators. The progress on the state of the art on this front will come from taking into account emotional data at both the individual and group level (GCP 2). Another direction, opening a new trend of research, aims at providing teachers with robust and efficient means to assess students' learning and improve their support for it. In the context of the data deluge, a new type of question emerges concerning the management of time and effort which may be required by assessment so as to preserve the time required by teaching (GCP 12, GCP 4). We see here the impact of the recent development of research on learning analytics. The strategy in this domain is not only to support learners but to enhance the quality and relevance of the educational offer (GCP 7). As a corollary, the idea of including data about teachers' activities appears with objectives as diverse as providing them with feedback about the emotional status of the classroom (GCP 4) or in relation to their own social responsibility as teachers (GCP 8).

The concept of smart cities (GCP 1) and the related research agenda offer a concrete framework for the idea that learning is at stake beyond schools and workplaces and concerns all citizens potentially in any activity. This is a new milestone on the route in the search for convergence and complementarities between formal and informal learning. The objective of building closer relationships between vocational learning and the workplace is more classical but it emphasizes the trend in the same direction (GCP 5). These grand challenges contribute to the conceptualization of *learning-aware environments*, that is, environments understanding learning needs and able to anticipate activities to respond to them with innovative pedagogies not only providing them just in time, and with just enough content but also adapting them to self-regulated and experiential learning (GCP 2).

Advancing the Scientific Field of Technology-Enhanced Learning

As it was required from them, all GCPs are formulated in terms of their practical or social relevance. However, they contain seeds for a TEL basic research program on questions that have not yet been addressed or have received little attention. The data now available, not only numerous but also diverse in nature and origin, must be modeled in ways tractable for computer-science and meaningful for educational purposes. The representation, the fusion, and the interpretation of educational data must allow for the confrontations of the different possibilities opened by the learning sciences and computer-science. The objective is to anticipate learning needs (GCP 12), to provide relevant feedback, and more generally to make decisions in order to support learning processes and to assess learning outcomes. These multiple perspectives call for new *collaboration frameworks where models would stand as boundary objects* open to *multivocality*,[1] complementary to the multidisciplinary approach claimed by TEL research. Such models do not yet exist; more often than not there is a convergence of theories in support of the design of a learning environment but with no clearly formulated views and arguments on the way one passes from the theories to the artifact.

The proposition to design teaching assistants (GCP 3) will open new ways of looking at teacher professional knowledge but also considering new pedagogical approaches that were not previously viable without the newest technological developments. The diversity of data enables researchers to address multiple dimensions of learning and develop multiple analytical perspectives. Such a context will allow us to provide support for learning that integrates individual styles, social characteristics, and specific contexts. Learning will then occur as if there were "*one tutor per child*", whereas instead there will be a community of human and virtual tutors—possibly peers—collaborating to support the learning process. In this sense, teaching will no longer be seen as the mission of one single agent, but as the result of the interactions between a variety of agents. *Teaching will become an emergent property of a complex system* equipped with competences to identify learning needs and to find the most adequate resources, be they human or artificial, virtual or material, in support of learning.

Ways Forward

The past decades have been marked by the rejection of the technology push to the benefit of a focus on learners' needs. One expression encapsulated the spirit of this turn: the "learner centered" design of learning environments. More recently and

[1] Multivocality—where researchers share corpora, focus their analyses of corpora through boundary objects, and examine the extent to which their different perspectives can build upon one another—could support us in relating theories and artifacts. See especially Suthers et al. (2014).

remarkably, with the adoption of the expression “Technology Enhanced Learning” as the new flag for the domain forged by the European Commission in the first years of the twenty first century, the figure of the teacher and of the trainer have recovered a legitimate place on the forefront of the research agenda. This evolution can be seen as a slow reconstruction of the foundational triangle of learning where the vertices are the learner, the teacher, and the content to be learned (or the trainee, the trainer, the content to be learned). Indeed, this triangle does not account for the reality of learning, structured by other dimensions and determined by several constraints, but it is a kind of kernel to which sooner or later everyone has to return. Then, I see one area missing in our research agenda: knowledge, taking this word not in its restricted sense of “academic knowledge”, but in the large sense of content at stake in the learning process. This content can have quite different forms including formal knowledge both conceptual and procedural, knowhow and “savoir-être”. Two GCPs touch these issues more precisely than the others: one when reflecting on the evolution required by Smart Cities in terms of the integration of learning content in technology augmented urban spaces (GCP 1), the other when considering the relations and transitions between vocational studies and the workplace (GCP 6). With the extension of the domains in which TEL is developing, our view of knowledge itself must be extended. Indeed, there are still open problems about the learning of the so-called formal knowledge, but with the development of simulations it is a large domain of tacit or embodied competences which can be considered, as well as ways of behaving that learning games and CSCL environments can develop by engaging learners in specific roles and complex social situations.

Although not expressed in these terms, several GCPs call into question and explore the teachers’ professional knowledge. The design of learning environments largely borrows from this professional knowledge although often not in an explicit way, and in return, the product of this design largely influences the evolution of this knowledge by eliciting its limits. This feedback loop results in a rapid obsolescence of the professional value of learning environments that at first appeared innovative. This is one of the lessons learned from the past decades, their consequences should be explored. The continuous feedback on teachers’ activity based on learning analytics associated with the capacity of virtual teaching assistants to be trained indicates a direction in which such issues could addressed.

The new dimension introduced by learning analytics inspired by business intelligence, reveals a tension between the macro level of learning environments which is the level of the decision makers and the micro level which is the level at which learning develops in the mind. Indeed, macro-level models suggesting statistically grounded decisions and orientation are not sufficient because in the end it is an individual who is learning and for whom we expect the best achievements. Yet, given the multiplicity of the social and environmental factors playing a role, knowing how learning functions in the brain cannot be the only prescriptive source of information. This suggests a shift of paradigm for TEL research from the question “how do human beings learn?” to the question “what are the best conditions for learning?” This change in orientation implies a deep integration of the different disciplines situating each in its own role and impact in terms of understanding learning and teaching. Perhaps orchestration of multivocality would be another way to look at scientific collaborations in the TEL research area. This could be a solution for a better integration of the research at macro and micro levels, research whose actors currently tend to ignore each other.[2]

Considering the TEL research area in terms of micro and macro approaches reveals serious issues at a scale we did not realize until recently, concerning the relations between learners and educational providers. There is a risk of dehumanization and commodification of educational experiences (GCP 9). Issues of privacy and ownership, of free will and democratic access to education must be investigated as well. Here is a new set of problems to which ethical and social studies will have to respond.

This series of GCPs illustrates the richness of TEL research but it also signals a large fragmentation of the research problems and of the related approaches. This fragmentation is tightly related to a fragmentation of the research community both geographically and scientifically worldwide. To respond to what is becoming an obstacle to the development of the TEL research area, one proposal takes up the challenge of creating a network of *small and medium laboratories* (SMLs), building upon and going beyond the former FP7 Networks of Excellence in the TEL research area (GCP 10). Such a network will be very relevant to the fact that in most countries, the research community is constituted by limited and very specialized teams. Being well connected, a SML network could react to a changing expression of needs and rapidly developing research in the related disciplines. It would also be the right platform on which to maintain existing scientific relations and contribute to the establishment of *the TEL knowledge base, possibly the most important challenge for the TEL research community*.

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[2]However, there have been attempts at relating such work at a series of workshops, for example: "Across Levels of Learning: How Resources Connect Levels of Analysis" at Computer Supported Collaborative Learning 2013 and "Computational Approaches to Connecting Levels of Analysis in Networked Learning Communities" at Learning Analytics and Knowledge 2014.

A Comment from a Practitioner Perspective

Peter Schwertschlager

Abstract This comment analyzes the 12 Grand Challenge Problems (GCPs) against the background of current reality in schools in the Bavarian part of Germany. The GCPs share a euphoric view on the benefits of technology-enhanced learning emphasizing the personalization of learning experiences and the increase in efficiency as well as quality of learning. However, there are still many barriers for technology-enhanced learning in current school practices on a less grand level than the proposed GCPs such as lacking internet access or legal restrictions. Another by the GCPs less addressed but crucial aspect for fostering the widespread implementation of technology-enhanced learning in everyday school practices is to get teachers aboard.

As a teacher and principal of a secondary school in the Bavarian part of Germany, reading the 12 Grand Challenge Problems (GCPs) raises several concerns about their implementation into practice. There are about 5800 schools in Bavaria; let me shortly describe their general conditions for technology-enhanced learning:

- In general, almost all schools have internet access. However, transmission rates vary greatly. Especially in the more rural areas, transmission rates are still unsatisfying;
- Most schools are part of an administrative network connected to the internet; this network is usually maintained by the municipality;
- The situation is different regarding the educational network which is required to be physically separated from the administrative network by law. We find different models of dealing with this situation:
- Some schools—only a few—have no internet connection for educational purposes at all;

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- Other schools maintain an intranet which is connected to the internet but only accessible in one or more specific IT rooms; other classrooms have no internet connection, but may have unconnected computers (and projectors) for giving presentations, using learning software, etc. This intranet is maintained by a teacher.
- The whole school has access to the internet for educational purposes as part of a larger educational network. This is only possible if the maintenance of all necessary services is outsourced. The largest educational network in Bavaria can be found in Munich, called M@School.

However, the recently started project "Digitales Bildungsnetz Bayern" (Digital Educational Network Bavaria) aims at integrating all 5800 schools (including approx. 1.7 million students and 200,000 teachers) in a joint educational network until the year 2020. This new educational network will be maintained and hosted by the state of Bavaria. As this is a very expensive endeavor politicians in charge wonder what outcomes can justify the efforts. At this point, we need to collaborate with researchers: technology-enhanced teaching and learning in educational practice is still in a very early stage. So, in my opinion, it is too early to discuss how to optimize technology-enhanced learning, but rather focus on how to successfully implement technology-enhanced learning to actually support learning in the current reality of schools.

Against this background, it is clear that the 12 proposed GCPs are quite ahead of the technical reality and practical problems we are facing in Bavarian schools right now. Most of the GCPs target older learners (high-school students, trainees, and grown-ups) who already possess the necessary prerequisites for self-regulated learning. However, according to my experience, this is far beyond the reality of teaching 10–18-year-old children, teenagers, and adolescents.

Furthermore, two main barriers hindering the implementation of technology-enhanced learning in everyday practice in schools are not taken into account: (a) issues of data protection and privacy as well as (b) copyright issues.

(a) There are very strict rules for handling personal data in Bavarian schools. For example, teachers are not allowed to see how other teachers grade the same student if grades are stored digitally. Therefore, ideas such as proposed in GCP 12 that require the collection, processing, and storage of personal data in real time, are simply not realizable. So, GCP 12 may be a very interesting research project, but is not transferable to the daily practice in school.

(b) The situation is quite similar regarding copyright issues: There are very strict rules regarding digitalization and dissemination of learning resources protected by copyright. Teachers usually want to use learning resources assembled in textbooks. However, these resources are of course easy to copy once they are digitalized. Authors of these learning resources, such as educational publishers, are very concerned that their work is not made accessible openly—and for free. So, even providing students with digital learning resources demands knowledge about and compliance with all legal requirements.

A further commonality between most GCP descriptions is the euphoric view on technology-enhanced learning and that it will for sure improve learning and teaching, if only the right data is collected, interpreted in an intelligent way, and then made accessible: Improvement will then happen automatically. But what are teachers supposed to do, if they are, for example, made aware that students' attention is declining at this very moment? A good teacher is able to notice this without technological assistance and takes the necessary educational actions. Less good teachers, however, will not benefit from the technologically provided hints if they have no idea of how to raise students' attention. Research, which does not take classroom reality into account to the necessary extent, is not helpful. Strong collaborations between researchers and school practitioners are necessary to prevent divergence between theory and practice.

Only few GCPs show a skeptical view on technology-enhanced learning (such as GCP 9) or explicate problems of technology-enhanced learning that need to be solved (such as GCP 5). Most other GCPs are based on the belief that technology-enhanced learning is per definition better than "traditional" teaching approaches. This is a mistake which already cost a lot of money in the past 20 years and also made teachers very skeptical about technology-enhanced learning. Most importantly, technology-enhanced learning must support education. So, the main question has to be: How can technology support teachers to further improve teaching? Media (as their name says) have always been and still are means of support for educational work in classrooms: not more, but also not less.

Finally, I need to address the time factor for solving the proposed GCPs: We see a range from 5 to 30 years. As said before, the project "Digitales Bildungsnetz Bayern" aims at integrating all Bavarian schools in a shared educational network and is so far planned until 2020. In my opinion, this is a very optimistic estimation taking the size of the endeavor into account. In ten years at the earliest, most Bavarian schools will have the technical equipment to implement the innovative ideas the researchers propose in the GCPs. Currently, there are only 400 laptop/tablet classes in Bavaria, i.e., only 11,000 of 1.7 million students (= 0.64 % of all Bavarian students) have the opportunity to benefit from technology-enhanced learning in its entirety. To provide the necessary technological environment in all schools for all students (broadband internet connection, educational network in the schools, hardware in all classrooms), we have to calculate with 200€ per student, meaning about 340 million Euro only for Bavaria. And this calculation does not even include a laptop or tablet for each student, let alone the costs for constant further maintenance.

But let us assume schools had all necessary equipment and infrastructure yet, what useful trends can we find in the GCPs:

We can see throughout the GCPs that the emphasis on technology-enhanced learning is no longer only one of the two advantages of making learning independent from location and time. Now, there is the new advantage that technology-enhanced learning becomes device-independent. I see this trend also in schools: A fast growing number of students (even in elementary schools) are in possession of high-end mobile devices such as smartphones or tablets with internet access via Universal Mobile Telecommunications System (UMTS) or even Long-Term Evolution (LTE). In general, the Bavarian Educational Law still prohibits the use of all kinds of digital storage devices in schools. However, schools are allowed to make their own rules and to permit meaningful use of digital devices. Most schools choose a pragmatic approach and let students, respectively, their parents, decide what devices they use. Therefore, I favor device-independent approaches and for most of the ideas described in the GCPs only a browser and internet access are required; all other resources and software can be found on the web. It is not necessary to install platform-specific software.

Another striking trend in the GCPs is the emphasis on **personalizing** learning opportunities. This approach is very interesting for schools. With increasing heterogeneity among students, we are looking for ways to support and challenge each student in the best possible way. The question is how technology-enhanced learning can help here. A current piloting approach in Bavaria is the implementation of a state-wide learning platform (Moodle). First results show already a great educational potential which, however, requires a lot of starting and maintenance efforts. I agree that the personalization of learning opportunities is an important direction of future technology-enhanced learning approaches.

Several GCPs aim at increasing the **efficiency** of learning and teaching. I see benefits and dangers at the same time in these attempts: Of course, teaching should be as effective as possible but investing in more effective teaching may raise policy makers' hopes to be able to reduce staff costs. Instead, it is necessary to investigate a reasonable reallocation of teachers' resources. At university level, for example, introductory lectures can be recorded and several cohorts can digitally access them from a university server. This frees lecturers' time and allows them to engage much more in high-quality personalized feedback for students. In secondary schools, teaching new topics can be optimized by digital recordings which students can access online. This brings up educational questions: Can students learn new topics at home so time in school can be used to practice and deepen knowledge? Does this approach not only increase efficiency, but also successful learning?

Also an increase in **quality** is an expected outcome of several GCPs (for example in the GCP about MOOCs). To me, this seems to be a realistic goal: After long-term trials (the first German laptop classes started in the end of the 1990s), it slowly becomes clear where technology-enhanced learning makes sense—and where it does not. One of the biggest advantages of digital learning resources is that they are easily adaptable to individual needs and that they can be improved gradually. If we manage to systematize this process, we can collect a body of best practices over the years which may actually allow personalizing the learning resources for each student much better than today.

Most GCPs have too high demands for the technical equipment of today's schools and are, therefore currently not implementable. They rather seem suitable for learning environments with good technical infrastructure such as universities, or vocational training and continuing education in companies.

Laws of data protection and data security set strict limits to most forms of data collection and analysis outside of research settings. This leads to the problem that research on technology-enhanced learning still relies and will also in the near future rely mostly on lab studies with volunteers—at least in Bavaria. The results of this kind of research are then, of course, not directly transferable to the reality in schools.

From the GCPs in this book, the most promising ones are those approaches that directly address the teaching situation, such as GCP 3, GCP 6, GCP 7, or GCP 11. However, in my opinion, the focus should not be on the development of "virtual teacher assistants". Although this sounds appealing, it will only be possible to prepare a few exemplary topics in STEM teaching but not the rapidly growing knowledge in natural sciences such as, for example, neurobiology.

And it may sound strange but technology-enhanced learning in schools is still in its infancy—at least in Bavaria, but probably also in the rest of Germany and other European countries. A lot of schools have laptop or tablet classes; they still are exotic isolated applications for a minority of students and teachers, quite often even within their school.

Only in the last few years has the technical development progressed in a way that we finally can start thinking about the establishment of an educational network to connect all students, teachers, and schools. It will still take years to master the technical (and financial) challenges that come with the design of the educational network.

With the implementation of the new internet platform MEBIS, the Bavarian Ministry of Education provides a powerful tool which may and should be of interest to learning researchers. MEBIS consists of two components: a learning platform (Moodle 2.4) and a media center with open access material which also can and hopefully will include digital textbooks soon. The project lernreich 2.0 about digital media based practicing and feedback in schools provides great opportunities for TEL researchers. The Bavarian prime minister announced in 2013 the goal to digitalize schools. If this declaration is put into practice, MEBIS will form the foundation of the new system. The internet infrastructure will be developed on the model in Munich and will provide all central services (including a tool for classroom management). This will leave more time on the side of system administrators at the schools to council and train their teacher colleagues.

All in all, I ask for an increased collaboration between research and practice in schools. One of the biggest questions is, for example, how subject matters can be orchestrated in a way that they can be taught within the 45 or 90 min of a class and then be further deepened by students at home. Here, I would not be so much interested in isolated cases but rather in transferable educational approaches that can be applied across subjects. Research on technology-enhanced learning is very important. Although I have emphasized that some of the proposed GCPs go far beyond the current capabilities of schools, I agree that envisioning the future in creative ways is an essential part of research. Nevertheless, I recommend and wish for more research in close collaboration with schools to prove that technology-enhanced learning is not only a vision of the distant future but can already be put into practice today.

Building the Future of the Digital Age School—A Comment from a Practitioner Perspective

Mikko Ripatti

Abstract An increasing number of students and pupils have constant access to the Smart phone, tablet computer, or an equivalent platform. They acquire, use, and share information in ways that are often different from the school's traditional practices. How do we take this into account in teaching? What kind of skills do the future teachers need in planning and implementing new ways of learning. Schools live in a period of transitional operations, which raises a number of questions. Many of them are discussed in the Grand Challenge problems presented in this book.

An increasing number of students and pupils have constant access to the Smart phone, tablet computer, or an equivalent platform. They acquire, use, and share information in ways that are often different from the school's traditional practices. How do we take this into account in teaching? How will technology enable us to strengthen the connection between formal and informal learning? What kind of skills do the future teachers need in planning and implementing new ways of learning? How can schools make better use of learning outside the school premises? How does e-learning change our behavior in learning situations? Schools live in a period of transitional operations, which raises a number of questions. Many of them are discussed in the Grand Challenge problems presented in this book.

In my school, Savonlinna Teaching Practice School, pupils and their teachers were given access 2 years ago to personal computers for learning instead of using textbooks. The name of the project was a Future Classroom 2020. Tablet computers have been used on a "one to one" basis. In the spring of 2013, the school conducted a survey of students, parents, and teachers. The survey, which compared

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the students' previous learning experiences without tablet computers and education with tablet computers that had been used for almost a year, brought up a number of interesting comments about learning. Their use in teaching was considered to have enhanced students' problem-solving skills and pupils' individual learning experiences. Also, learning by doing, as well as research-based learning increased as compared to the past. The tablets were viewed to have changed the educational action of pupils and the working atmosphere in the class became better than before. Students also got more pleasure from doing homework. Learning from each other increased, and the trial made significant contributions to the ways in which a culture of sharing between both pupils and teachers could be constructed. Yet, parents wanted their children to do more schoolwork and considered that school performance decreased. In fact, we learned it was necessary to challenge schools and homes to more closely cooperate. In this chapter, I will review this book's Grand Challenges in TEL from these experiences.[1]

Digitalization of society and culture changes the educational structures and our way of learning and studying. As learning is increasingly moving toward its happening outside of formal education, the demand for the development of practices of the traditional school and general education is increased. If we do not develop our educational practices, there is a danger of them conflicting with the habits of the young, causing the legitimacy and credibility of school in the eyes of young people to be in decline. This is reflected in a growing indifference toward school and education and thus leads to more and more extensive questioning of the school environment as well as the need for strengthening class management and the disciplinary system.

This set of Grand Challenge problems raises new perspectives on learning and education and suggests ways of developing current practices. Together they seek to solve our educational challenges, which are common in Europe and around the world. In the background there is a strong common view that technology is capable of producing more and more modern learning with more quality.

Against this background the GCP 1 on People Centered Smart Cities through Smart City Learning by Giovannella, Martens, and Zualkern draws attention to the current school, the heart of the matter. How can we strengthen formal and informal learning and the integration of them both? The article suggests that the solution should center on place and content, roles and skills, and monitoring and evaluation. Chanel, Lalanne, Lavoue, Lund, Molinari, Ringeval, and Weinberger review the social regulation of emotions in online collaborative learning environments in GCP 2. This plays a very important role in the success of collaboration and in online learning. A new pedagogy is needed to support the social regulation of emotions in online learning contexts and to prevent new social problems such as cyber-assault and cyber-bullying. The attention of both articles could be more student-centered: in my experience students (pupils) are nowadays building their own personal learning environment and networks more and more. This requires ever-increasing self-regulation of emotions but also self-regulation of their own

[1]See http://snor.fi/futureclassroom/in-english.

operations management. Without these types of regulation, operating in an informal Smart City environment is very difficult. How could we support pupils and students more effectively—in particular, in Smart Cities?

Science, technology, engineering, and mathematics (STEM) are reported as the key sources for technological innovation in the twentyfirst century. Pedaste, Lazonder, Raes, Wajeman, Moore, and Girault ask in GCP 3 how science teachers could improve inquiry learning using technology-enhanced scaffolding. A key for solutions are these three main phases: firstly, to revise and re-design STEM education and environments. Secondly, to employ virtual assistance to support teachers, learners, and their interactions. And thirdly, teachers' professional development should be enhanced with the virtual assistance that could empower them. Cuendet and Tormey focus on supporting teacher decision-making through appropriate feedback in GCP 4. Feedback to teachers about their teaching has been found to have a bigger impact on pupil success than any other type of teacher-based intervention. The feedback to teachers can include information on student learning and the emotional state of the classroom. Cuendet and Tormey propose to develop more effective models of feedback to teachers in order to support them in the management of both learning and emotional states of the classroom. This can help teachers to maintain job satisfaction. My own experience in attempting to improve inquiry learning and pedagogy has generally required that teachers share their pedagogical innovations and collaborate on improving them. Benchmarking studies can inspire and engage teachers to develop their pedagogical activities, for example how to use tablet computers in the part of inquiry learning.

The GCPs on vocational education (GCP 5 and GCP 6) and massive open online courses (MOOCs) (GCP 7) deal with the organization of education and training in a new way. They are atypical for the primary school system. Schneider and Zufferey are bringing the information and communication society to vocational education and training. The digital generation possesses good communication skills that are focused on networking and sharing simple digital artifacts. Learners, particularly in the vocational education and training sector, could become active "connecting" information workers but bridges must be built between theory and practice, and school and the workplace. Vocational education must be reorganized as a learning community that shares and connects experiences within its boundaries and within the workplace and must include all the groups involved. European universities are facing a massification of education. Running such large units and classes leads to high drop-out rates due to the absence of guidance, interactions, and feedback by the teachers, standardized instead of personalized learning experiences, and students with a very superficial and short-lasting knowledge. The challenges of MOOCs include the change in the value of formal qualification as well as the upcoming importance of e-portfolios and badges resulting from formal and informal learning activities. Mödritscher, Luengo, Law, Hoppe, and Stegmann aim at enhancing MOOC experiences in terms of efficiency and quality of study programs. Thus they propose to develop adaptive and adaptable learning on massive online courses.

Will MOOCs eventually become available to all students or only be selectively available to particular students? The focus of the following chapters of education is on such social issues. This perspective is important for social capital and for the organization of school activities. How could Learning Analytics be considered as a “democratic turn”, which would facilitate a better management of accountability and opportunities in educational settings? Learning analytics should support not only tutors and teachers in reflecting on and improving their teaching activities but also learners who should be included in a dialogic process of quality of management, and developers who would be empowered to improve their educational software and content. This might have a positive effect on the quality of study programs and the efficiency of the educational institution. Mödritscher, Luengo, Lai-Cong Law, Hoppe, and Stegmann argue in GCP 8 that all groups concerned (learners, teachers, curriculum designers, educational managers, policy makers, software developers) should take an active part in an iterative and interactive analytics process in order to improve learning.

In GCP 9, Beetham, Perrotta, and Holley focus their attention on the problems of the TEL project in Europe. Although access to educational opportunity is extended by the availability of open learning materials, learning communities, and new forms of learning, the problem is the uneven distribution of digital access and know-how. This has introduced new inequalities in participation and in educational outcomes. The open digital landscape favors globally successful institutions and puts pressure on the local languages, practices, and educational systems that are most able to support those who are currently disadvantaged. The TEL project has led to more technical, managerial, and commercialized approaches to education. This has weakened the historical commitment to education as an emancipatory project and a democratic right. This research agenda puts technology at the service of citizenship, social participation, and equality of outcome.

In GCP 10, Dirchinck-Homfeldt’s, Balacheff’s, Bottino’s, Burgos’es, Dimitriakopoulou’s, Ludvigsen’s, and Mille’s focus is an incoherence of TEL research in Europe. Europe has dominated the small and medium-sized research labs within the TEL research. This is justified by the great numbers of countries and regions in Europe and by the diversity of cultural and institutional educational systems. Much implementation of ICT has taken place without systematic research and without linking research and educational practices. Researchers propose to build an agile knowledge infrastructure based on small and medium-sized research labs (SMLs), which have TEL as their main research field. This infrastructure is based on a vivid network and a community of practice, which can support building of new research capacity, better integrating research labs, and aligning and synthesizing research findings from different traditions: educational, psychological, social, and tech-research. The target is interesting, but it raises the question of how to build access to teacher training. If we want to disseminate results to the schools and influence educational practices, the connection to teacher training is essential. This is one reason why all of teacher education (pre-school, classroom, and subject teachers) in Finland is in the university.

Wasson, Hanson, and Mor suggest in GCP 11 empowering teachers with student data. Technology-rich learning environments generate rich streams of data pertaining to students' and teachers' actions and their outcomes. This data can help teachers to monitor and improve their practices, but new methods and skills are needed that help teachers to harness and interpret this data and incorporate it into a framework of continuous professional development. On this basis, Wasson, Hanson, and Mor have developed a model of teacher-led design inquiry of learning and innovation cycle. The goal is to empower the teachers with new methods and practices that will improve their teaching as well as student learning, and will make the teacher's profession more attractive.

Molenaar's and Wise's GCP 12 is the assessment of student's learning through a continuous collection and interpretation of temporal performance data. Their aim is to integrate learning and assessment into a single process. Advances in data collection and analysis technologies present the possibility of tracking and interpreting the traces the students naturally leave behind while learning as evidence of their development over time. The main problem is the lack of robust assessment schemes that provide valid and useful information about student learning over time without sacrificing the learning time for testing. This chapter's attention is drawn to the teacher's activities. Tracking and interpreting students' traces is very important for teacher's professional development, but progress still needs to be made in supporting the student's learning process.

Grand Challenge problems are acute. They are justified perspectives and ways of developing education in the European context. The articles raise a number of key trends, which are related to each other and connected with each other.

The first article deals with various types of learning analytics, as well as e-learning as new techniques to help in the collection, interpretation, and use of information. As a consequence, technology-supported learning environments have become increasingly common. Traces of student activity provide new opportunities for teachers to reflect on their teaching and their students' learning process and to further develop student learning related to their own teaching practice. At present, schools do not have many experiences of this kind nor do they have methods or tools to analyze the data. New kinds of evaluations will change the assessment of learning and the culture of evaluation in schools. The question in this regard is the development of cultural activities in schools. It is especially important to find a way to analyze the data-relevant information, which ultimately has a bearing on student learning.

Although the assessment system would provide new tools and methods for evaluating student learning, the issue is still the application of this information to a large number of pupils. One teacher has a class of 20–30 students to be taught, thus a real-time individual assessment and implementation of the learning process may become a challenge.

Another key theme is linked with vocational training and a question of how theory and practice could be better integrated. Of particular importance is the question of how we can produce more high-quality education for the needs of the future information society. This question is highly relevant to teacher training, while figuring out what skills teachers, pupils, and students need to possess in the future. The development of the information society in this regard is shaking the foundations of all types of training and forcing us to review them over time.

The third theme is related to MOOCs and education of the masses. Central to this is especially e-learning-related research and diagnostics development. Several Grand Challenge articles have failed to take into account the student's individual needs. They do not always recognize the context and will be experienced as distant and without adequate social interaction. The younger the pupil, the more important this lack of personal adaptation and of social interaction becomes. New e-learning practices require skills that emphasize the student's self-control and self-regulation. This requires more and more demanding pedagogical skills of a teacher. It is also why the topic of research should be to better identify the goals of a teacher's educational foundation. Where can the student's needs be identified and taken into account in an increasingly personal way? In studies, the student is too often seen as a techno-rational being, who can be influenced in one way, all students being equal. However, classroom social reality is complex and children have very different starting points. Usually pupils and students come from different (social, economical, ethnical, ethical) backgrounds and their cognitive characteristics are often very different.

Technology also impacts young people and is a source of inequality. The question of how technology may underlie the values of education is extremely important. The school as an institution has the responsibility of maintaining social cohesion that allows the development of society. Education and training should not be subject to any form of technology on the sole basis that such technology is needed for the execution of technical, administrative, and commercial aspects of institutional projects.

The development of the information society will change the economic structure of society and the source of citizens' livelihood. More than half of the EU-countries' gross domestic product is expected to be related to digital activities in the beginning of 2020s. This change is essentially attributable to the education qualification. The aim is to produce a higher quality of learning. But this will not happen just by introducing information and communication technology in schools. It is essential to think about the ways in which the learning and working cultures in schools should be developed so that they can respond to a changing society. In the future, focus should be more on the skills of the future and how to educate for those skills (Ripatti 2013).

Reformers should focus on creating an educational system that supports inquiry-based, student-centered learning, where students are encouraged to find entry points into the mandated curriculum in ways that are meaningful to them. Technology is an integral part of this vision, because it allows students to create and demonstrate their knowledge.[2]

[2]See http://blogs.kqed.org/mindshift/2014/02/what-would-be-a-radically-different-vision-of-school/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+kqed%2FnHAK+%28MindShift%29.

Related to everyday life in the schools, the key aspect is whether we carry out consumer-centric school activities or producer-based pedagogies? The three most common pedagogical practices in schools in different countries are completing handouts, simultaneous activities carried out by working groups, and independent study. Generally, teachers have looked for ways to teach all the students in the same way at the same time to be able to later test them. Information and communication technologies have been found to be variable and one-sided (OECD 2014; Law et al. 2008). The most popular wishes of the students, in turn, are to have their own learning and group work, to do practical things with their friends, and with the help of computers, or to study alone. The most common forms of learning in reality, however, were copying from the board or a book, the teacher talking and listening, carrying out class discussions, and note-taking at the same time the teacher is talking (OECD 2008).

Consumer-centered pedagogy is understood to be tasks carried out by the students, supplemented by the use of workbooks, where online activities fill in the empty gaps. In this type of pedagogy, the student listens, performs, reads, commit to memory, and writes notes.

An alternative to consumer-centered pedagogy is producer-centered pedagogy where students should be producers of their social world by genuinely collaborating in the processes of research, teaching, and learning (Neary 2010). They pose questions, collect and share information on resolving a set of research problems. At the same time, they produce learning materials for each other. This requires active data acquisition, construction, and operation. Student activity should be directed so that assessment is possible (e.g., activity generates an output artifact that can be evaluated). Current technology offers schools a better chance to attain producer-centered pedagogy than ever before in the history of the school system. In technology-enhanced learning, a student should be seen more and more as his or her own learning facilitator and builder. The future school student is an active participant, who produces his own learning artifacts, alone or in collaboration with others.

For the school's development, it would be important to explicitly express the vision of the kind of pedagogy and learning the authors of the Grand Challenge problems wish to support technologically. What kind of pedagogy is expected from the schools in the future? Should schools teach knowledge rather than the skills that are necessary in the information society? It is important to motivate teachers and principals if we want to achieve consensus on a new vision of school and the challenge this vision requires for the development of education. The Grand Challenge problems presented can in this book develop education as it is related to real problems and raise important issues to be discussed. A future vision of school must begin with reforming current existing practices and then set school reform goals even higher. These Grand Challenges in TEL are an important step toward this goal.

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What Do Policy Makers Learn from Foresights Around ICT-Enabled Learning—A Comment from a Policy Maker Perspective

Lieve van den Brande

Abstract The 12 Grand Challenges notified in this book provide a wealth of information and ideas to guide current policy makers to shape long-term policies and actions. These Grand Challenges are being formulated at a time when more and more of us are recognising the increasing importance of ICT in and for education and the necessity to find solutions to overcome the enormous gap between education and all other sectors of life and work. Three imminent trends identified along the 12 Grand Challenges note a fundamental paradigm shift in the role of new technologies supporting educational change. But this is not enough. The focus should be no longer on ICT tools and infrastructures but on open and flexible learning and teaching with the learner (and the educator) at the centre. This shows that the step from an early adoption of ICT use in education towards mainstreaming has started. It is all about the core business of education: Learning.

What is on the horizon for technology-enabled learning in 2020 or 2030? Which trends and technologies will drive educational change? What are the challenges that we consider as solvable or difficult to overcome, and how can we strategise effective solutions? These questions and similar inquiries regarding technology adoption and educational change steered this publication about Grand Challenges in Technology-enhanced learning.

In the first part, high-level European researchers propose 12 important Grand Challenges to be tackled in the near future. But how are these Grand Challenges and their possible solutions taken up by policy makers in the area and have long-term impact on policy making in Europe? What are the mechanisms of uptake and

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further mainstreaming of these Challenges into education and training and in general skills development?

Foresight as a Valuable Policy Instrument

While increasingly moving towards evidence-based policy making in education and training, these 12 Grand Challenges provide a wealth of information and ideas to guide current policy makers in their work. Identifying the problems of today's society and reflecting on possible solutions in the future gives a policy maker the much needed knowledge, evidence and instruments to define future actions in a period of time—from five to sometimes 20 years.

The 12 Grand Challenges around ICT-enabled learning discussed in this book gather information on emerging issues and trends in education and training in an increasing digital society; identify core problems and possible actions to address these. As such, these 12 foresight studies are an important instrument for policy making as they explore the future of scientific and technological achievements and their potential impacts on society in terms of education and skills at large. They identify the most important areas of technological development most likely to bring about change in the educational world and drive economic and social benefits for the future.

The 12 Grand Challenges enable policy makers to look into the future in order to identify and choose among policy options as well as to shape long-term policies and actions. The 12 Grand Challenges provide a framework to policy makers with common issues at stake around ICT-enabled learning to jointly think about the future in a structured and constructive way. They provide tools to develop visions of the future and pathways towards these visions and are as such a valuable policy making instrument.

What Do Policy Makers Learn from These Grand Challenges?

These 12 Grand Challenges are being formulated at a time when more and more of us are recognising the increasing importance of ICT in and for education[1] in the coming years and the necessity to find solutions to overcome the enormous gap between education and all other sectors of life and work which have been already embedding the potential of technologies.

[1]The term 'ICT' in this paper is often used instead of 'technology-enabled', as it is best understood and most used by policy makers. However ICT, digital or technology-enabled can be considered as synonyms.

Three Imminent Trends Can Be Identified Along the 12 Grand Challenges

First, today's learners are despite being digital natives not competent to use technologies in a creative, communicative, collaborative and safe way. The digital generation of the twentyfirst century is not at all digital savvy.

Secondly today's learners demand a more personalised, learner centred education with increased facilities for collaborative learning across time and space and more emphasis on blending formal education and informal learning. This requires changing the role of educators and enabling them to use large amounts of data on individual students and group behaviour, emotions and learning progress over time.

Thirdly, learning organisations such as schools, universities as well as more informal learning facilities are increasingly opening up their educational content, services and practices. The traditional services are being unbundled and new 'business' or implementation models have to be developed. Among these services assessment, validation and recognition of what has been learned have risen in importance and are seen as the most important trend and challenge in the near future.

Trend 1: Digital Competency for All

Grand Challenges 5, 6 and 9 address the digital competency of our digital generation of learners, highlighting the lack of skills to use technology to manage, acquire, share and co-produce knowledge. Challenge 5 focuses on the vocational education and training (VET) sector making use of real-world experience and connected learning among communities of practices and peers. Also Challenge 6 focuses on the dual learning approaches in the VET sector whereby learners have to bridge practical experience in a working environment with more conceptual knowledge in a traditional classroom environment. Challenge 9 opens up the debate towards the unequal access and participation of some groups in the European society and the necessity to take adequate measures towards real open education.

The messages given by these three Grand Challenges underline that all young European citizens need to be digital savvy both towards employability and active citizenship. These challenges confirm the ongoing concern by today's policy makers as well as educational practitioners regarding the insufficient digital competency levels of EU citizens, and in particular youngsters, and recommend some actions what policy makers and practitioners can do to develop, recognise and embed technologies into education and training in ways that are both effective and sustainable.

In the context of the Grand Challenges shaping our world today, the input of education and training is more critical than ever to help people by improving their skills and preparing them for the new opportunities in a changed economy. We must ensure that people have the right skills. One of these core skills for life and employability is the confident and critical use of information, media and technologies.

Nearly all future jobs will require in one way or another digital competences. Digitally competent people are in high demand across all economic sectors. In 5 years time only 10 % of jobs in the EU will not acquire these digital skills. In spite of high levels of unemployment, there is strong evidence of skills bottlenecks and mismatches around digital skills and this not only in the ICT sector but across all labour market sectors. Demand for ICT practitioners is growing by around 4 % a year. The shortages would amount to around 500,000 unfilled positions in 2015 and up to 900,000 unfilled ICT vacancies in 2020. This means we must develop the digital competences of the EU's 500 million citizens and develop a new generation of digitally competent youngsters.

However, the *supply* through education is not sufficient. The EU population lacks sufficient digital competences, including the so-called 'digital young natives' who, despite being more acquainted with technology than older generations, do not have enough and the right skills to use new technologies in a critical, collaborative and creative way.

Learning digital competences is not sufficiently addressed by formal education (European Union and European Commission 2012a, b, 2013; Fraillon et al. 2013; Johnson et al. 2014b; Ranguelov et al. 2011; OECD 2011, 2013). Formal education institutions, pedagogies and curricula do not sufficiently embed and assess digital competences. Only 17 % of secondary education pupils are critical users of digital skills. Sixty-three per cent of 9-year-olds do not study at a highly digitally equipped school and only 20–25 % of students are taught by digitally confident and supportive teachers. Between 50 and 80 % of students in EU countries never use digital textbooks, exercise software, broadcasts/podcasts, simulations or learning games. Most of the learning of digital competences happens outside school.

Thirty per cent of all Europeans are even digitally illiterate (older people, less educated youth, from lower income families; migrants, at risk of social exclusion in general, etc.) and are as such deprived of e-government; e-health, e-banking, etc., services.

Having not the necessary digital competences has direct consequences for employability: In several EU countries, at a time when an ever-growing number of jobs require digital skills, half of the people with no core computer skills are not working. But also inverse, being inactive in the labor market has a strong impact on chances of developing skills, including digital skills. Of those surveyed who did not have digital skills, 42 % were inactive.[2]

[2]A new report from the European Commission (2014) has underlined the importance of tackling the digital skills gap.

Those youngsters who are not able to use new technologies will be excluded from an increasing digital society. Digital competences are therefore not only important skills for employability but also a core life skill. We need to invest in digital competences of all EU citizens to make sure that no-one is left behind as the economy and society go digital.

The Grand Challenges also address the question on 'How one can teach digital competency'. Surveys as ICILS (Fraillon et al. 2013) and PIAAC (OECD 2013) have shown that digital competences are not given but can effectively be learned and, thus, taught. While learning digital competences happens mostly outside formal education, it is a must for formal education to embed it in its curricula and the related learning outcomes[3] and increase the use of ICT to innovate and modernise its learning environments. The new generation of learners is no longer the people for whom traditional educational systems were designed to teach in the twentieth century, and their needs and expectations differ fundamentally. The learners of today live in environments where technology plays a crucial role. This calls for a renewed look at how in formal education one can learn and teach digital competences and which learning and teaching environments in our schools and universities are required in the twentyfirst century.

Concerns about digital competency of EU citizens surfaced as a solvable challenge in Europe, largely due to ongoing actions of stakeholders and policy makers in Europe. The work by the European Commission on the development of a common European Digital Competence Framework[4] is a good illustration. To address this problem and to bridge the worlds of education and labour market, the European Commission developed a common European Digital Competence Framework to identify and describe the set of competences that are needed by all citizens today. Participation in the digital domain is no longer a question of "have" or "have not", but rather an issue of competence. This framework is oriented to *all* European citizens as users of digital technologies and complements the existing e-Competence Framework oriented specifically to ICT professionals.[5]

The European Digital Competence Framework for citizens[6] describes 21 competences to use digital technologies in a confident, critical, collaborative and creative way to achieve goals related to work, employability, learning, leisure,

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[3]Learning outcomes are statements of what a learner knows, understands and is able to do on completion of a learning process, defined in terms of *knowledge, skills* and *competences* (European Centre for the Development of Vocational Training (Cedefop) 2009).

[4]See 'OpenEducationEuropa' portal website: http://openeducationeuropa.eu.

[5]See www.ecompetences.eu.

[6]The European Digital Competence Framework was developed through an intensive 2-year process of collaboration and validation involving more than 120 experts and stakeholders from many different countries. The research was developed by the European Commission Institute for Prospective Technological Studies (JRC IPTS) on behalf of the Directorate General for Education and Culture and Directorate General for Employment, Social Affairs and Inclusion. It has been endorsed by EU Member States' representatives in the E&T2020 Thematic Working Group on 'ICT and Education'. For details on the development see Punie et al. (2013).

inclusion and participation in society. Digital competence is one of the eight key competences for Lifelong Learning by the European Union (see European Parliament and European Council 2006). It is a transversal key competence which embeds more than only ICT functional skills; digital presence depends more on knowledge, skills and attitudes than only on access to and use of pure functional ICTs. In the framework, each of the competences has three proficiency levels, namely “Basic user”, “Intermediate User” and “Proficiency User”.

Several EU Member States are already implementing the framework as a comprehensive approach to identify, describe and assess digital competence. A more European application is the individual online assessment tool of one’s own digital competence levels that has been embedded in EUROPASS. This online tool is available free of charge for everyone through an online portal.[7]

The importance for each EU citizen to be sufficient digitally competent has been a recurrent issue under the former Europe 2020 flagships such as the ‘Digital Agenda’, the ‘Agenda on New skills and Jobs’ and ‘Youth on the Move’. It is even more an important issue under the new Juncker’s Commission. The Framework supports key policy objectives of Juncker’s Commission and in particular the Political Guidelines on ‘A New Boost for Jobs, Growth and Investment’ and a ‘Connected Digital Single Market’ and relies on past Commission initiatives such as “Rethinking Education” and “Opening up Education” as well as the “Grand Coalition for Digital Jobs”. It benefits an ever-growing user community from the EU and across the world. The Digital Competence Framework is also contributing to turn the Youth Guarantee into a reality to ensure that every young person gets help to find either a decent job or the opportunity to find training, experience or learning relevant to getting a job in the future.

Trend 2: Towards Personalised, Learner Centred Education with Increased Facilities for Collaborative Learning

The second trend that is demonstrated by the Grand Challenges is the importance of innovative learning through technologies and in particular the potential that these have to support personalised and collaborative learning.

It is not only about learning technologies but also how technologies can support and innovate learning and teaching. Through the use of technologies one can learn differently (more individualised, more personalised learning pathways tailored to needs and abilities; more active cooperation through learning communities; other content which is difficult to learn otherwise (simulations; modelling; experiental; etc.) and learn about other competences such as collaboration; learning-to-learn;

[7] See https://europass.cedefop.europa.eu/en/home.

active learning and initiative taking; creativity, critical thinking, etc. This is the ultimate goal of ICT, being an enabler, an instrument to improve the learning process.

Grand Challenge 3 addresses how technology-enhanced learning has the potential to support inquiry and authentic/real-life learning, in particular in science, technology, engineering and mathematics (STEM) education. The potential of technologies for online collaborative learning is the subject of Grand Challenge 2. Due to the use of new social media technologies (blogs, forums, social networking sites; virtual teams; etc.) interactivity between peers has increased but demand specific challenges. Challenge 2 in particular looks into the ability of learners to understand and manage emotions in self and others in online collaborative learning environments.

The trends and challenges identified by these Grand Challenges illustrate perfectly what is actually at stake in the educational world. Personalisation both in terms of equity among all learners[8] as well as in terms of individual learning plans and tailor-made learning activities is one of the main challenges posed to education and training. Today's learners in an increasing digital and global world do not learn anymore the same way as a century ago. Still, the ways learning is offered and organised are heavily based on objectives of the last century.

Making learning more adapted to the individual needs of any learner is the big question of the near future. A mix of different technologies can support personalisation, by allowing for a diversity of learning activities, tools and materials; providing tools which support continuous monitoring and assessment strategies; making educational resources openly available; allowing for the implementation of collaborative projects; offering learning opportunities that are motivating, engaging and even playful; and supporting multilingual environments.

Collaboration with the community at large, and with people from other social, cultural or age groups will become increasingly important. Virtual study exchange programmes, internet-based intercultural exchange projects, online massive multiplayer games, simulations creating and sharing OER with peers and other internet-based services can serve educational institutions in allowing learners to experience, understand and reflect upon societal developments in a safe and protected environment.

Policy makers at regional, national and European level are well aware of the challenges for more personalised and collaborative learning. On 25 September 2013, the European Commission presented a new Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on "Opening up Education: Innovative teaching and learning for all through new technologies and Open Educational Resources" (European Union and European Commission 2013). The aim of this initiative is to bring the digital revolution to education with a range of actions in three areas: open learning environments, OER, and connectivity and innovation.

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[8]Special needs, remote learners, early school leavers, migrant children, adult learners, unemployed, etc.

This EU initiative on “Opening up Education” is one of the examples of how policy makers are responding to the emerging trends and challenges in ICT and education and is described and analysed in the 12 Grand Challenges. The initiative contributes to the Europe 2020 strategy, acknowledging that a fundamental transformation of education and training is needed to address the new skills and competences that will be required if Europe is to remain competitive, overcome the current economic crisis and grasp new opportunities. Innovating in education and training is a key priority in several flagship initiatives of the Europe 2020 strategy. The Opening up Education initiative also highlights the importance of better knowledge and evidence-based foresight to develop policies for teaching and learning which ensure that all learners benefit from new technologies and OER.

Trend 3: Open Education, Assessment and Recognition

Grand Challenges 4 and 12 look into big data and in particular learning analytics as a support for assessment and open recognition of competences. The discussions go beyond the potential of learning analytics to gather student’s performances but also for information on the individual learner and classroom learning processes. Current assessment practices are driven by the need to evaluate student’s performance and not the way a student learns and progresses over time. Issues such as what should be measured and how to advance understandings of how learning processes unfold over time are being analysed.

Grand Challenges 3 and 11 look into learning analytics from the side of the teacher and how analysis of complex student data can empower the teacher in order to monitor and improve their teaching practices; attention is given to embed learning analytics in teacher education and training.

Grand Challenge 7 also focuses on analysis of large amounts of user-generated data in order to support individual and group learning such as applied in massive online courses. In view of the ‘massification’ of education like it is expected at European universities, one-to-one interaction among learners and between learner and educators is enormously important but costly. If no solution is offered in terms of increased guidance and/or feedback by teachers to the individual learners, high drop-outs will be noted. Only standardised learning experiences instead of exciting individual learner experiences will take place.

Grand Challenge 7 links learning analytics of learning processes also to the problem of recognition of informal learning and the upcoming importance of assessing and valuing the competencies of learners on the basis of former learning experiences through e-portfolios, badges, etc.

Assessment has only recently come into the picture of policy makers but is considered as one of the most crucial parts of learning that requires changes nowadays. Learning analytics offers great opportunities for improving (i) assessment, which could go beyond single exam moments to a continuous evaluation based on the learning path (“formative assessment”) using learning analytics; (ii) personalisation, e.g. recommendations for further learning according to interest or weaknesses/strengths and (iii) individual feedback for learners and educators which can feed into the learning process.

Another important trend taken up by policy makers is that a lot of learning takes place outside formal education and that this informal and non-formal learning should be recognised and validated. Relevant skills, knowledge and competences can, and often are, acquired outside of the formal education and training system, for instance through life and work experience. In particular, digital competences have been shown to be acquired mostly outside formal education (also due to the fact that educational systems are very slow to embed the potential of ICT use). These should be valued and it should be possible to make them visible and usable through a validation process. The validation of this type of learning can support, for example, the increasingly widespread use of technology-based learning (such as OER, including MOOCs) by documenting, assessing and certifying the related learning outcomes.

Non-formal and informal learning can play a crucial role in enhancing employability and mobility, as well as increasing motivation for lifelong learning. This is especially needed in times of economic crisis and skill mismatching in Europe. For individuals, validation can broaden their opportunities for finding a new job or for further skill development through education. It can also improve their self-awareness and self-esteem. For companies, this means having a better picture of the skills possessed by an individual, therefore ensuring a better match with the job requirements.

This is why the Commission is supporting EU Member States in developing national arrangements for the validation of non-formal and informal learning and following up to the Council Recommendation of December 2012 (Council of the European Union 2012).

Mainstreaming of ICT Use for Learning Is Highest on the Future Agenda

The three trends identified along the 12 Grand Challenges are clearly influencing the thinking and work of policy makers. These trends and challenges are of course not falling out of the blue and are being confirmed by other recent long-term horizon reports such as Horizon Report Europe: 2014 Schools Edition, co-authored by the European Commission and the New Media Consortium (NMC) (Johnson et al. 2014),[9] the work by the European Commission on the 'Future of Learning'

[9]And the related NMC Horizon Report: 2014 K-12 edition (Johnson et al. 2014b) and NMC Horizon Report: 2014 Higher Education Edition (Johnson et al. 2014a) as the world's longest-running exploration of emerging technology trends and uptake in education.

(Redecker et al. 2011), and ‘Open Education 2030’ (Castaño Muñoz et al. 2013)[10] and other forward-looking surveys on ICT and education (Sharples et al. 2012; Kampylis and Punie 2014).

While these foresights are very valuable and useful for future policy making, some critical parentheses have to be made. These foresights—and this is also the case for the 12 Grand Challenges—still take a very technocratic look at the problem and possible solutions. While there is a clear attempt—more than ever has been taken in the past—to put the learner and the learning process at the core of the analysis, still the Grand Challenges are discussing more the *technology* dimension in technology-enhanced learning and less the *learning* dimension.

The most urgent issue in the near future to be solved and thus the greatest challenge in the coming years, is to find adequate ways to embed the use of ICT into the actual learning and teaching processes and to assure that the potential of ICT to enhance and modernise educational systems becomes a reality.

New technologies can have an extraordinary effect on improving the efficiency, accessibility and equity of education, training and learning. Learning and teaching can become more focused on the learner supporting the individual learning pathways, enhancing collaboration online and blending formal and informal education. Personalisation, collaboration and links between formal and informal learning enhanced by technologies will be at the core of future learning and push educational institutions towards opening education and institutional transformation.

However, literature and practices show that education is one of the last societal sectors in Europe, which has not yet embedded the potential of new technologies, failing to provide European citizens with the skills necessary for the future. Europe is not fully reaping the potential offered by new technologies and the upsurge across the globe of digital content, including Open Educational Resources (OER), to improve the efficiency, accessibility and equity of its education, training and learning systems. In a digital world, this has serious consequences for citizens who do not possess the skills necessary for social and economic well-being. In the last years the lack of systemic uptake of new technologies in education has been a concern for many EU countries but with scattered efforts. Despite the investments, a full uptake of new technologies and OER requires more than dispersed action. Evidence indicates that the EU-wide experiences on innovative learning need to be scaled up into all classrooms, reach all learners and teachers/trainers at all levels of education and training.

The new ways of looking at learning through technologies require a rethinking of the educational landscape in terms of access, quality and efficiency. Past experiences have shown that any initiative to overcome the implementation gap of using new technologies in education requires a 360° approach or (eco) system-wide, and

[10]Following the Opening up Education, the Institute for Prospective Technological Studies (IPTS) worked on a participative extensive foresight study to develop different scenarios for Open Education in 2030, which illustrate how opening up education can improve learning opportunities for different learning situations and learning needs.

not a piecemeal approach. A full uptake of new technologies requires more than boosting experimentations across Europe.

Over the past years several large-scale pilots have been implemented across Europe, crossing national countries and some even of European dimension such as: One-to-one learning initiatives providing every child or teacher with a personal device; eTwinning, a European-wide community of schools; large-scale experimentations providing real-life laboratories of scale to develop and test scenarios for mainstreaming innovative use of new technologies in education; Open Courseware; MOOCs changing the European higher education landscape and large-scale platforms for open education. The European Commission also introduced under the Lifelong Learning programme and the ongoing Erasmus+ programme a new instrument to respond to the need of large-scale policy experimentations.[11]

While more research is needed on how we can develop, sustain and further implement the existing initiatives of ICT-enabled innovation for learning, best practices examples provide some ideas on possible conditions for sustained and scalable impact on learning to realise the potentials of ICT to support learning. Eight main conditions enhancing mainstreaming of ICT use in education in terms of an innovation process have been identified.[12]

Successful scaling up and uptake of the use of new technologies in education only takes place if it looks into learning and teaching taking a holistic and whole system approach whereby common vision, strategies and agenda are being defined and agreed upon by all stakeholders and all dimensions in the learning and teaching processes are touched upon (from content and resources, curricula, learning and teaching strategies; assessment, learning outcomes, etc.). Successful uptake is thus context-dependent and there is no one-size-fits-all approach.

Most of the practices of ICT-enabled learning innovations started as incremental efforts from a single pilot in one classroom, in a single school, to networks of schools across countries, etc., and progressively moved towards more radical forms of innovation, indicating that these initiatives have developed organically over time. Their successes are clearly not a consequence of blueprints, but rather that dynamic adaptations and adjustments were continuously developed and implemented as an integral part of the monitoring, evaluation and feedback cycles, which is consistent with an ecological model of change.

Successful scaling up only happens when the use of new technologies is linked to a clearly articulated educational objective improving access, quality and efficiency of education. A well-articulated innovation agenda and accompanying roadmap of implementation (business plan) should be developed by each

[11] See https://eacea.ec.europa.eu/erasmus-plus/funding/key-action-3-prospective-initiatives-european-policy-experimentation-eacea-102014_en.

[12] See also the Staff Working Document accompanying the 'Opening up Education' Communication (European Union and European Commission 2013).

educational organisation—which has both long-term vision (ensuring policy support) and achievable short-term goals for the progressive take up of innovation.

Another common characteristic of successful practices is that while most of these started as top-down initiatives within their respective contexts, they all have mechanisms in place to encourage and support bottom-up approaches to the innovation. While learning innovations may be initiated even at the classroom level by the teacher, impact at scale cannot be achieved without some higher level support as such innovations inevitably impinge on curriculum and assessment practices and require access to technology infrastructure and support. One of the core conditions crucial to the scalable success of these initiatives is the deployment of top-down strategies to support bottom-up innovations.

Research reveals that successful scaling up and uptake of the use of new technologies and OER in education only takes place if there is organized support to foster connectedness[13] across and within different levels of stakeholders involved in the innovations to build trust, assure mutual objectives and create a common vision (Kampylis et al. 2013). Communication channels and platforms should be built to foster dialogue, communication and collaboration between all stakeholders (from policy, industry, research, educational practice and the wider public) involved and engaged in the educational process.

Thus, an important message deriving from the analysis of the 12 Grand Challenges is that it is utmost important *to move away from a technology-centric approach*.

While the 12 Grand Challenges note a fundamental paradigm shift in the role of new technologies supporting educational change, it is still not enough. The focus should be no longer on ICT tools and infrastructures but on open and flexible learning and teaching with the learner (and the educator) at the centre, enhanced through new technologies. This indicates that the step from an early adoption of ICT use in education towards mainstreaming has been started. It is all about the core business of education: learning.

This does not mean that technologies are not important but these should be seen as an underlying condition enhancing online learning. It is time that the *technology* dimension in technology-enhanced learning is changing towards “learning through the support of technologies” or “technology-*enhanced* learning”. Technologies are just an enabler, not a goal.

Upcoming initiatives at national as well as European levels are showing that this message has been well understood. To reinforce digital skills and learning across Europe, to empower Europe’s workforce and consumers for the digital era and to support Member States in tackling existing skills mismatches, there is a need for a package of measures boosting digital skills. Based on the in-depth foresight work, among which the 12 Grand Challenges discussed here, a package

[13]Connectedness refers to the social and emotional factors that profoundly affect the relationships among members of a learning institution and that have a significant impact on their level of engagement and motivation (see Bocconi et al. 2012).

of measures will be defined under the Digital Single Market strategy as one of the Commission's top 10 political priorities. It is also a key priority for the European Council and the European Parliament and has been highlighted in the Annual Growth Strategy 2015. The Strategy focuses on various strands: building trust and confidence, removing restrictions, ensuring access and connectivity, building the digital economy, promoting e-society and investing in world-class ICT research and innovation. Among these the digital skills—as one of the core skills for employability—will be addressed with a clear link to other upcoming work of Europe on the EU Skills for Employability in 2016.

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