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Digital Futures

Expert Briefings on Digital Technologies for Education and Research

Edited by Martin Hall,
Martyn Harrow, and Lorraine Estelle

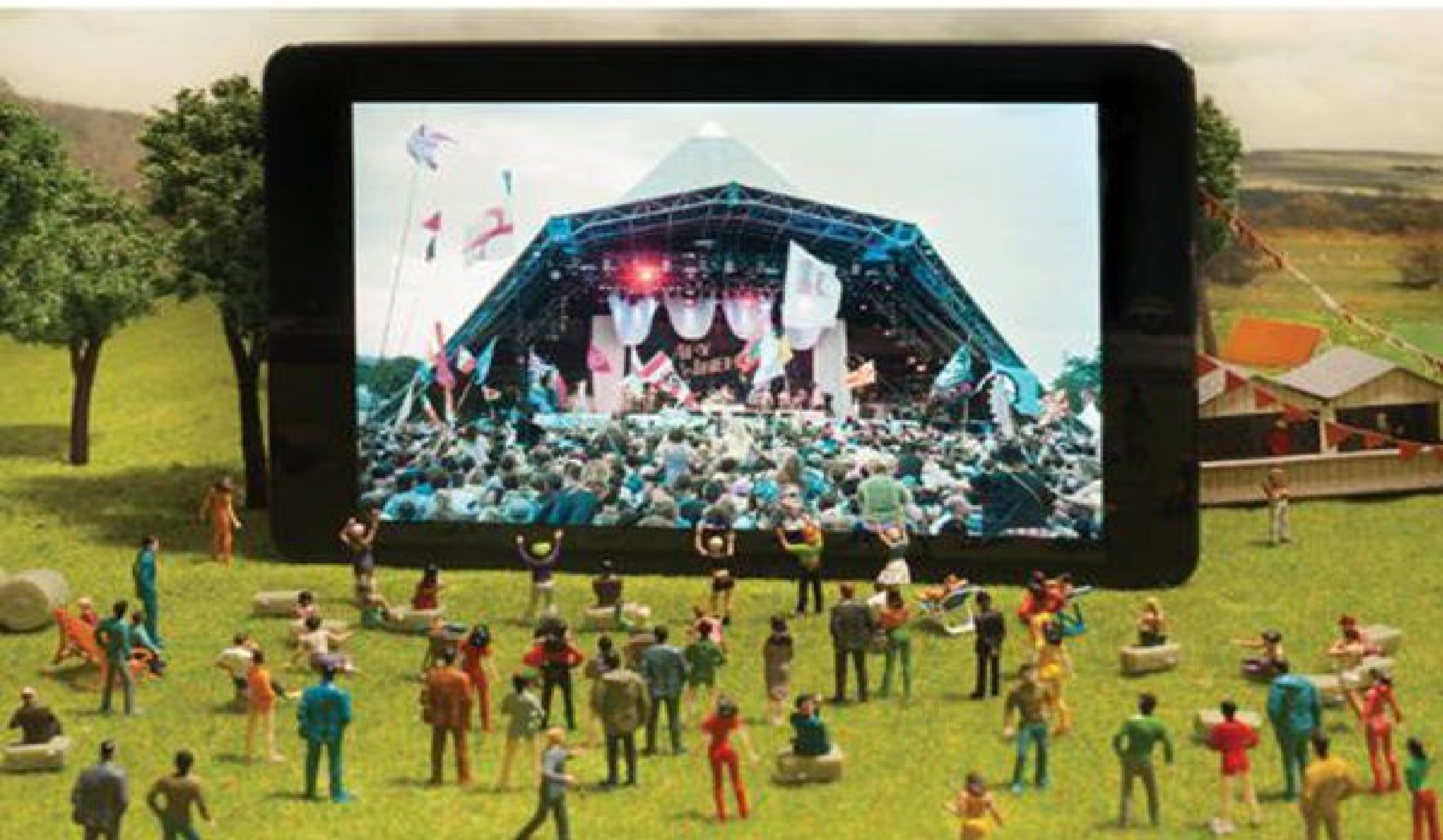

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Table of Contents

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About the Editors

Martin Hall is Chair of Jisc and Vice Chancellor of the University of Salford, UK. He is a British-South African academic and educationalist who he has written extensively on South African history, culture and higher education policy. Prof. Hall was a member of the Working Group on the Finch Committee which examined Open Access policy in the UK.

Martyn Harrow has extensive strategic experience in both public and private sectors. Before taking up his position as Chief Executive of Jisc in February 2012, he was director of information services at Cardiff University where he was responsible for IT and also the university's library service, media centre and high-performance computing. Previously Martyn led ICT for global companies within Unilever and ICI. At various times he was responsible for IT across the USA, Europe, Africa, the Middle East and Asia while based in the UK and the Netherlands. He also has experience in local government, having held a senior role at Avon County Council.

Lorraine Estelle has been Chief Executive of Jisc Collections since 2006. She has overseen the organisation's growth and development and has been heavily involved in all aspects of national procurement and licensing activities for academic libraries. She has initiating a range of fruitful projects and services around the use, management and delivery of digital resources. Since May 2013, Lorraine has also taken the leadership role for all Jisc's digital content and discovery-related people, organisations, strategy, services and operations. Lorraine is also co-editor of *Insights*: *the UKSG journal*.

About the Contributors

David Kernohan is senior co-design manager, at Jisc. He works on online learning, research data management, student innovation and open education. He's an expert on English higher education (HE) policy and global HE trends and previously worked as a policy analyst for HEFCE.

Frank Manista is the Community Engagement Officer for Jisc Monitor.

Jo Lambert is Project Manager at Jisc. Current work includes managing UK shared analytics services such as the Journal Usage Statistics Portal (JUSP) and Institutional Repository Usage Statistics (IRUS-UK), as well as open access projects such as Jisc Monitor and CORE (Connecting Repositories).

Andrew Cormack is Chief Regulatory Adviser at Janet, having joined the company in 1999 as Head of CERT.

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His role involves informing Janet and its customers on the regulatory and security aspects of current and future Janet services. He is particularly interested in how technological developments can improve both security and privacy while making our working and private lives easier.

He was a member from 2005 to 2015 of the Permanent Stakeholders Group of ENISA (European Network and Information Security Agency) and a personal member of FIRST (Forum of Incident Response and Security Teams). He has contributed to the development of laws including the Computer Misuse, Defamation, Copyright and Digital Economy Acts. He teaches both face-to-face and online training courses and is a frequent speaker at national and international events.

Rachel Bruce is Jisc's innovation director for digital infrastructure. She oversees Jisc's innovation programmes which relate to digital preservation, management of research data, resource discovery infrastructure, open access of scholarly communication, geospatial infrastructure and resources as well as some activities associated with open educational resources.

Andy McGregor is Jisc's deputy CIO, with responsibility to ensure that Jisc innovation work is more closely aligned with customer priorities and to deliver the new products and services that customers need.

Sarah Knight is a Senior Co-design Manager in the Student Experience team in the Jisc Digital Futures directorate. Sarah currently manages the Digital Student project which is researching students' expectations and experiences of the digital environment in further and higher education. Sarah also has responsibility for supporting the Jisc funded Change Agents Network, a national network to support staff-student partnership working on technology enhanced curriculum projects.

Sarah has managed the production of numerous internationally acclaimed Jisc publications including the 'Emerging Practice in a Digital Age', 'Effective Assessment in a Digital Age', 'Effective Practice in a Digital Age', 'Designing Spaces for Effective Learning' and 'In Their Own Words'.

Sarah also established and runs the Jisc Learning and Teaching Practice Experts Group, an active community of practice, which provides valuable consultation and dissemination opportunities for Jisc.

Sarah has worked for Jisc for 11 years and during her time at Jisc has led large programmes of work on curriculum design, digital literacies and learners' experiences of technology.

Matthew Dovey oversees work within Jisc developing the digital infrastructure services needed to support and enhance aspects of the research lifecycle. He is chair of the Executive Board and Council for the EGI (http://www.egi.eu) and holds membership of the UK Cabinet Office Open Standards Board and the Software Sustainability Institute Advisory Board.

Introduction

The UK academic sector is successful on a global scale. It not only contributes more than £73 billion to the national economy each year, but also produces some of the most groundbreaking research undertaken anywhere in the world, and is highly effective in the commercial exploitation of that research, leading to significant economic return and societal impact. While the UK represents just 0.9% of the global population and 4.1% of the world's researchers, it produces 15.9% of the world's most highly cited articles.[1] The sector excels not only in research but also in teaching, with a world-class reputation across teaching, research and knowledge transfer.

A contributing factor to this success is undoubtedly the investment made by UK funding bodies in a world-class shared digital infrastructure, which includes a secure network dedicated to the needs of research and education. At the research level, this enables large data storage and high-performance computing facilities to be linked both nationally and internationally. The infrastructure also includes eduroam, the worldwide single sign-on secure network which provides Wi-Fi connectivity to more than 600,000 Internet-enabled devices in the UK. The UK national infrastructure encompasses not only technology but also digital content, with negotiation and licensing for academic journals and databases along with the national provision of digital archives to support innovative research and education.

However, the academic sector faces many challenges if the UK is to sustain its position as a world-leading research and education nation. Global competition from emerging nations is a significant threat. The volume of research outputs from China is increasing at an exponential rate and the indications are that the quality of those outputs (measured by citation impact) is also rising.

Other pressures on the sector come from competition in the provision of education, both within the UK and globally. International students are important to the higher education sector and to the country, contributing more than £7 billion to the UK economy. A recent report by Universities UK points out that international higher education is an increasingly competitive market: 'the governments of the UK's competitors – including the USA, Australia, Canada, New Zealand and Germany – are each implementing bold strategies and policies, backed by investment, in an attempt to attract more international students to their own universities'.[2]

The introduction of student fees is having an impact on the expectations of UK students. Kandiko and Mawer have shown that 'UK students across all year groups, institution types and subjects have a consumerist ethos towards higher education, wanting "value for money" '.[3] These students expect technology to provide access to resources and to support their studies.

The developments and innovation that digital technologies provide could have a crucial role in enabling UK universities to respond to competitive pressures and remain world-leading across teaching, research, knowledge transfer and international outlook.

In preparing this book, we were keen to ensure that it covered all the major aspects of the digital technologies that will enable the UK higher education sector to remain a global leader. Thus, we have chosen authors who are not only leading experts in their fields but who are also proactively engaged in developing those technologies that both support the sector and enable innovative change.

MOOCs

The first massive open online courses (MOOCs) were launched in 2008 and MOOCs have grown rapidly since. Currently, UK institutions offer around 60 MOOCs. These online courses attract thousands of participants, are open to anyone to join, are free to undertake and are delivered fully online, thus transcending the spatial limitations of a traditional classroom. MOOCs are usually fairly short in duration, running from between 5 and 10 weeks, and require limited lecturer input. Participants are able to study anywhere at any time and at their own pace. If they wish, participants can also benefit from interaction with other learners, through message boards.

The benefits of MOOCs are not confined to those studying on them. The mass of data gathered from observing and recording learners' online behaviours, discussions and assessment scores has the potential to help educators to improve courses and plan interventions that will support learners. These learning analytics may provide insights not only for improving teaching through MOOCs, but also those taught through a 'flipped classroom' pedagogical model which blends online teaching and learning with more traditional methods. Use of the flipped classroom in the UK has seen Jisc do pilot work with institutions to produce 'video lectures' which students watch in their own time to free up valuable tutor contact time for more interactive teaching.

Some MOOCs report impressive completion rates. Take, as an example, Edinburgh University's Equine Nutrition MOOC, one of first to be offered by the university. From an initial enrolment of 24,000 people, it achieved an 80%+ conversion rate from enrolment to active participation, with a completion rate of 30%.[4] However, other MOOCs report retention rates as low as 7–9%.[5] In a globally connected world, even such low conversion rates provide universities with a potentially huge marketplace. MOOCs offer an opportunity to rethink the possibilities of education and the business models that underpin it. For example, higher education institutions could make their teaching and teaching materials free, but charge for assessment, accreditation and, possibly, optional extras such as one-to-one tutoring. Such models would open up franchising opportunities, enabling strong brands to maximise their global potential with local provision for participants. Universities may, of course, also use MOOCs to drive recruitment to their more traditional campus-based courses, or to more selective and paid-for online courses.

MOOCs also present potential challenges to the established education sector in terms of new entrants. For example, educational publishers with their vast banks of learning materials could enter the market. Some companies already derive considerable income from K–12 level online testing and may seek to expand into higher education.

In his chapter on MOOCs, David Kernohan discusses many core issues around pedagogy and business models that are yet to be resolved and asks if MOOCs can prepare institutions for the wider challenges they now face or if there may be more effective ways forward.

Open Access

Free and open access to publicly funded research offers significant social and economic benefits. In the last few years, the UK government and UK funders of research have been at the forefront of supporting a transition to open access, helping to ensure that publicly funded research outputs are not only widely available to other researchers, but also to potential users in the business, charitable and public sectors and to the general public. The publication of the report of Dame Janet Finch's working group, *Accessibility, sustainability, excellence: how to expand access to research publications* (often colloquially referred to as the Finch Report) in June 2012 was instrumental in driving this change towards making all UK-funded research outputs open access. Most significantly for UK higher education, this report recommended 'a clear policy direction in the UK towards support for "gold" open access publishing, where publishers receive their revenues from authors rather than readers, and so research articles become freely accessible to everyone immediately upon publication'. These author payments for immediate open access publication are known as article processing charges (APCs).

As a direct result of the recommendations in the Finch Report, Research Councils UK (RCUK) issued its policy for open access with a preference for gold open access and provided block grants directly to research organisations primarily in order to help them meet the extra cost of APCs. The extra cost of meeting APCs (in an environment in which the research outputs from most of the rest of the world are still behind paywalls) is a contentious one. Estimates of how much the potential cost of transition to open access will cost the UK higher education sector vary. Steven Hall, a member of the Finch Group, calculated that using an average APC of £1,727 (as estimated by Finch modelling), the bill for publishing the 31,000 papers RCUK estimates it funded in 2010 would be in the region of £53.5 million. Hall suggests 'it would require several other major countries to make the same commitment [towards gold], for the balance to tip irrevocably towards an OA publishing model'.[6]

The cost of implementing open access policies is not limited to the payment of APCs. Engagement with stakeholders and the development of new workflows and standards are required to make open access a reality. Frank Manista and Jo Lambert have been working with UK higher institutions as they face these challenges. Their chapter discusses how authors, universities, funders and publishers can support open access implementation in order to make it a success.

Managing Digital Risks

As discussed above, a significant factor in the success of the UK higher education sector to date has been government investment in a secure academic network. Most recently, this has included investing in Janet6, an upgrade to the UK's academic network, to ensure it has the capacity, resilience and flexibility for research and education, across the UK, for the next 5–10 years. The functionality of Janet6 will enable the research and education sectors to make the most of technological advances, and to address the political and financial challenges of the future. These advances will likely include greater use of cloud technologies, so that data storage can be outsourced, resulting in reduced financial and environmental costs.

Our national network provides a route for the information most critical to the functions of educational organisations, whether for teaching, research, administration, employment or funding to be secured, stored and shared using cloud technologies. The effective operation of all those functions depends on reliably accurate information being available when it is needed by those who are authorised to see it, and equally reliable security to ensure that such information is not disclosed to those who are not authorised to see it. Andrew Cormack's chapter takes a broad view of the risks to these aspects (accuracy, availability and confidentiality of information security); examines the origin of these risks in behaviours, processes, physical, technical and environmental factors; and considers how policies can be used to mitigate and manage the risks.

Open Data

Just as the open access publication of research outputs has the potential to increase the reach and impact of publicly funded research, open data has the potential to break down traditional barriers, enable transparency and the use and reuse of data and allow for new types of research. Organisations of all types are opening up their data and harvesting it in interesting new ways to make it more useful for education, research and administration. Gavin Starks, CEO at the Open Data Institute (ODI), recently said: 'A smart country requires open data. The UK is a world leader in higher education and it is an obvious step to use open data to improve outcomes for both universities and students. Universities need to understand, embrace, and publish open data – using transparency to both improve and create new services, to pave the way for open innovation, and enhance their existing work'.[7] However, the Royal Society report on open science argued that openness itself has no value unless is 'intelligent openness'. Prof. Geoffrey Boulton, chair of the Royal Society's science as an open enterprise working group, said: 'Science is vital to many of the dilemmas that confront us, but needs to be communicated intelligently, by which we mean it must be supported by evidence, which must be accessible, intelligible, assessable and usable. The internet and other digital technologies offer great ways for scientists to feed these wider demands for information and evidence'.[8]

Rachel Bruce and Andy McGregor have been working for many years on the standards that will contribute to 'intelligent openness'. In their chapter they point out that the government is ahead of the UK academic sector in terms of a coordinated open data strategy and its implementation, and discuss the issues that the academic sector must address in order to catch up. Although these issues are not insignificant, they argue that the potential for efficiencies and innovation are so great that the UK higher education sectors should 'step up and grasp the nettle of open data'.

The Digital Student Experience

The way in which UK higher education meets the needs of students is fundamental to its ongoing success in the increasingly competitive global education market. It seems clear that the majority of students in UK higher education share the common expectations that their university will provide ubiquitous connectivity to a robust network, that they will be able to connect their own devices easily and that they will have access to digital content and software relevant to their studies. Beyond that it would seem that while student expectations are rising, they are more varied, depending on the subjects they are studying and their previous experience of ICT. Helen Beetham, in her recent Jisc blogpost, points out that every student she has spoken to in the last few years has made clear 'that they don't want technology to be a substitute for "the real people, in the same place, learning together" '.[9] Sarah Knight supports this in her chapter on *enhancing the digital student experience*, arguing that working in partnership with students to engage them fully in the development of the digital environment is critical. She proposes seven key principles that universities and colleges can follow to fully realise the vision of a digitally enabled student experience.

International Collaboration

In a world in which many research challenges are too big for a single institution to tackle, and the best facilities attract the best researchers, institutions must collaborate in order to remain competitive. Furthermore, many of the issues we face, for example, changing patterns of human population and consumption, climate change and global pandemic health challenges, are global problems and require the input of international networks of scientists. The growth in the number of scientific papers published with international co-authorship points to the important role of collaboration among researchers.

Digital technologies enable researchers to collaborate in cross-disciplinary, international teams by sharing resources such as research data, computing power and software over the Internet. In his chapter on *International collaboration and the changing digital world*, Matthew Dovey explains that a robust e-infrastructure is essential. He cites as examples initiatives such as GÉANT, which links Europe's National Research and Education Networks (NRENs), connecting users at over 10,000 academic institutions across Europe, and eduroam, which ensures access to wireless networks in campuses around the world. He also explains why virtual research environments (VREs), which sit alongside the e-infrastructure, are becoming increasingly important to enable collaborative research without regard to physical location. Dovey points out that while we are seeing increased collaboration enabled by technology, there are still challenges to be overcome, not least the interoperability of emerging technologies and the skills of researchers to use them effectively.

Collectively, these expert briefings provide a summary of the advantages that the UK higher education sector can gain through the effective use of digital technology for its own research, teaching and learning, the student experience and competitive positioning internationally. They highlight the role that digital technology can play as a driver for change in universities and as a useful enabler of better research and better learning rather than as just yet another challenge to be overcome. Universities will face immense challenges in the years ahead, but through harnessing the power of digital technology, and actively engaging with some of the developments outlined in this book, they will not just be able to survive, but to thrive.

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CHAPTER 1

MOOCs

David Kernohan, *Jisc*

This chapter considers MOOCs, their value and possible futures.

Keywords

MOOCs; higher education; government; policy

As the MOOC snowball – it was never an avalanche, for all the feverous hope of former Blairite aides – crumbles and melts across the stinging and red-raw face of UK higher education, what should be our reaction? The icy water of the postulated disruption trickles down the collective institutional neck as we wonder if we should join the jeering young upstarts in their game, or maintain our distance and dignity.

Or are we too late? The painful brilliant ice thrown back in 2012 has become a greying slush, a dampening rather than a disruption. As the shining crystals decompose, should we be preparing for a brilliant new season of online education?

1.1 The Melting of the MOOC

It can be argued that you need just one graph to rebut the hyperbole. Katy Jordan's (2014) interactive chart of MOOC retention rates is continually updated to reflect new data concerning the percentage of students who sign up for a free online course who complete it. Most MOOCs (though there are outliers, particularly where the initial cohort is smaller) have a completion rate of less than 13%.

And this is what it should come down to. If you offer the proverbial free lunch, you'd hope that lot more than 13% of those who accept it would eat it. The promise of the MOOC was – initially – one of a more engaging and personalised educational experience. 'Inspiring and rich learning' ran the promise around the launch of FutureLearn's first course in 2013, though in reality people have been less inspired by video lectures and multiple-choice quizzes than one might hope. Pedagogic innovation in MOOCs has, so far, been limited.

Sebastian Thrun and Peter Norvig's 'first MOOC', the Introduction to Artificial Intelligence (AI) course they offered out of Stanford in late 2011, heralded much of the early excitement about the use of AI in massive online education. Throughout 2012 (though less so latterly), we saw a range of claims concerning the insights that massive learner data could offer to course design and delivery.

For example, during her 2012 TED talk Coursera founder Daphne Koller (2012) said:

> *You can collect every click, every homework submission, and every forum post from tens of thousands of students. So you can turn the study of human learning from the hypothesis-driven mode to the data-driven mode, a transformation that, for example, has revolutionized biology. You can use these data to understand fundamental questions like, what are good learning strategies that are effective versus ones that are not?*

Very little of note regarding learning has been yet been discovered via this methodology (for an overview see Reich, 2015), though the need to collect user data permeates much commercial MOOC course design. 'Content that talks back' must sit on a suitable platform that is able to return reliable data about every aspect of learner activity. All of which adds to overheads and mitigates against the wider (open) exposure of materials that have been produced, often at great expense, by institutions keen to promote themselves and their work.

This data gathering also prompts enormous ethical issues. The data trails are so personal that they are very difficult to anonymise, and there is no 'opt-out' for people who wish to use the resources but not have their data collected. For serious education research, as MOOC data mining often claims to be, this is essential practice.

The former minister of state for Higher Education, (David Willets 2013), had a particular fondness for the MOOC movement, though he did tend to conflate it with the wider issues of online delivery and learner analytics. He saw the MOOC as a tool that could 'revolutionise conventional models of formal education' and 'sources close to the minister' claimed 'In ten years' time there may be just one university or platform offering online courses and it may have become the dominant player worldwide'. However, he remained less bombastic concerning the precise method by which this would happen. Like many he used Bower (1995) language of 'disruption' as a way to encapsulate this promise; broadly the idea that a lower cost, lower quality, alternative to a monopoly (in this case, traditional higher education (HE)) would attract new customers and destabilise the market.

The trouble with this, and as Christensen et al. (2013) acknowledged in their revised thoughts on disruption for education, is that a low-quality education is not just a less 'premium' product, but a product without a purpose. This is Sebastian Thrun's (2013) 'lousy product', one with a low-to-zero value to customers other than as a digital distraction.

A recent report from Which Higher Education (2014) suggests that only three in ten current undergraduate students would be interested in replacing some aspects of a traditional degree course with online delivery if it lowered costs. So there is – perhaps – a market for lower cost, equivalent quality, education, but it addresses a particular subsection of learner needs and aspiration. This is perhaps behind a shift in key platform offers.

1.2 From Education to Training

In talking about MOOC platforms, the tendency is to imply Coursera, Udacity, EdX and maybe FutureLearn. But there are more than 40 platforms, ranging from government-funded collaborations, to for-profit enterprises, to charities, to offerings from learning management system vendors. And this doesn't include the independent MOOCs that are more likely to use the highly extensible WordPress blogging platform than anything else.

So to talk meaningfully about trends in MOOCs is close to impossible. But certainly across the big three or four platforms, the movement has been in two directions: charging students for certificates and additional services, and building links with employers. Gone are the early statements about education for all, this is a clear attempt to build both a value case for learners to complete MOOCs and a viable business model.

Let us start with the latter. Coursera, Udacity and EdX are all primarily supported by venture capital investment. Though all are starting to generate their own income streams from learners and employers, these are dwarfed by their obligation to provide a return to investors and – indeed – their running costs. Audrey Watters' (2014) 'Hack Education' weekly news has a 'MOOCs and UnMOOCs' section which details the often humorous attempts by platforms to raise money from increasingly unlikely partnerships. (The UK's FutureLearn, being entirely owned and funded by the Open University, feels similar pressures but to a lesser extent.) To give a few examples, Coursera has entered a partnership with budget airline JetBlue to provide in-air video content, Coursera and EdX are attempting to gain US Federal funding to provide certificates to in-service teachers and military veterans, and Udacity – now no longer offering free courses – work with a range of employers including Facebook and the Bank of America.

Working with employers is presented as a way to add value to the student experience – allowing a 'certificate' to be awarded that is recognised by the employer in question. And this extra value is charged for, ranging from £26 for a FutureLearn certificate to $200 per month for a Udacity 'Nanodegree'. From the perspective of the employers and the platform, this looks like it is offering the student a cheaper way to access jobs that demand specific skills. However, such an approach means that the student would lose out on having a transferable accreditation that they could use with a range of employers.

1.3 Fight or Flight

But back to our snowball – how big is it (realistically) going to get? What are the risks of not being involved, and – conversely what are the risks of being involved? To read much of the invective, from Martin Bean (2012), about 'getting on board the MOOC train' you may think that this should be a foregone conclusion. 'MOOC or die', as I once heard a very senior academic (who should, quite frankly, have known better) tell a conference.

Look at the UK institutions that have yet to experiment with MOOCs: Oxford, Imperial, Durham, St Andrews and (barring a targeted maths GCSE offer) Cambridge. Most of these domestic and global league table dominating institutions have yet to enter the world of MOOCs. As we know FutureLearn are focused at the top of the league tables – and Coursera invite the top five institutions in any given country – it is clear that many institutions must be saying no to the big platforms. Why?

As indicated above, it could be because they offer institutions and learners so little benefit compared to alternative investments. Oxford University, for instance, has focused on offering 'open education resources' (OER), drawing together activity from across the institution to offer materials that can be freely reused. The LSE, to give another example, have invested in working at the boundaries of academia and journalism via a successful series of blogs, many of which are openly licensed for reuse only latterly supporting (not leading) a World Bank-led MOOC on the Coursera platform.

St Andrews was named as an initial FutureLearn partner, but appeared to pull out before the beta platform was launched. It has since focused on promoting the quality of its research via a dedicated hub and has developed an OER offer around Maths and Statistics.

There is a cost attached to developing a free course, conservatively estimated at around £30,000–40,000 but likely in reality (including overheads) to be substantially higher. It's an expensive club to join, and as with so much else in modern higher education, it is an expense that is being looked at critically. With the MOOC 'first mover advantage' now a fading dream, and with around 105 free courses starting globally in November 2014 alone, institutions no longer develop MOOCs to stand out but to fit in. The days of gushing press coverage simply for launching a free online course, a 'year of the MOOC' staple in 2012, have long since passed.

But the ubiquitous acronym (first coined by Dave Cormier of the University of Prince Edward Island back in 2008) shows no sign of disappearing. Amongst senior managers and faculty, ‘MOOC’ has become a shorthand for any kind of online learning, and in a sector seeking to consolidate income online instruction has once again become a huge area of interest. Jisc’s ‘Scaling Up Online Learning’ activity has demonstrated a huge UK-wide appetite for peer support and advice in this area.

In Further Education, the much-discussed FELTAG requirements around blended learning, with an emphasis on tuition without direct teacher interaction, have a clear basis in MOOC pedagogy. Despite concerns about engagement and learning quality, it seems that online content delivery in isolation from educator interaction will be a recognisable facet of the experience of many students.

What is less clear is whether the MOOC experience can prepare institutions for the wider challenges they now face. At worst, what we are seeing is simply a retread of enterprises like ‘Fathom’ and ‘AllCourses’ in the early 00s – enterprises that made a huge deal of noise about how the Internet was changing education, spent a great deal of money that they didn’t earn and crashed quietly, alone and unloved, in the darker corners of the post dot-com crash Internet.

And, as the explosion of new platforms has proven, we have learnt very little from that experience. Sustaining a viable online offer requires real investment in academic and technical staff, and still remains at least as expensive to offer as a similar quality on-campus course. And open publication can greatly increase the visibility of academic activity, but to maximise this benefit it should be genuinely open to reuse.

No one could criticise the nobler aims of the MOOC, to bring education and opportunity to the world. But there may be more effective ways to reach that goal.

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CHAPTER 2

Open Access

The Costs and Opportunities

Frank Manista and Jo Lambert, Jisc

For research funders, scholarly publication delivers crucial public benefits: funders' open mandates in the UK are making open access (OA) a reality. The implementation of these policies requires positive engagement from all stakeholders, in the development of new standards, workflows, best practice and cost models. Through a discussion of the costs and opportunities, this chapter will outline how authors, universities, funders and publishers can support OA implementation in order to make it a success.

Keywords

Open access; OA; Finch Report; UK higher education; funding; cost; opportunity

2.1 Introduction

Open access (OA) to the outputs of publicly funded research offers social and economic benefits and supports development of new research, something that's being encouraged through the policies of government and funders.

Policy changes following the recommendations of the 'Finch' Report[1] in 2012 on how to increase access to published research has presented a number of challenges and opportunities to institutions, researchers, funders and publishers. The independent working group on OA, chaired by Dame Janet Finch, recommended a programme of action to enable all to read and use the outputs of publicly funded research. The report outlined several options for encouraging greater OA but recommended a policy direction in support of 'gold' OA publishing, where the author pays an article processing charge (APC) to publish their article in a pure OA or hybrid journal. The government, broadly supportive of the report, looked to the funding councils to implement the recommendations with support from key stakeholders.

More recently, in July 2014, the four UK higher education funding bodies introduced a new OA policy, which requires that anything to be submitted to the post-2014 Research Excellence Framework (REF) has got to be made OA. To be eligible for submission, authors' final peer-reviewed manuscripts must be deposited in an institutional or subject repository at the point of acceptance for publication. The 'Policy for Open Access in the Post-2014 Research Excellence Framework' also indicates that:

> *Higher education institutions are now advised to implement processes and procedures to comply with this policy, which may include using a combination of the 'green' and 'gold' routes to open access. Institutions can achieve full compliance without incurring any additional publication costs through article processing charges. We will be working closely with Jisc to support repositories in implementing this policy, and will issue further information on this work in due course.*[2]

The shift in policy means that OA has become an interesting, controversial and compelling requirement for grant-funded recipients to comply with. If institutions and researchers want to prove impact and relevance, they must comply with the OA requirements of their funding. However, policy compliance and management of APCs presents new requirements and demands new ways of working that can result in time consuming and costly administration challenges for universities. In a rapidly evolving landscape, communication and collaboration amongst a range of stakeholders is key to progress. Therefore, it's crucial to ensure that OA is as successful as it can be and to assess what needs to be in place to support and guide those key stakeholders in the current landscape. The costs and opportunities in a transition to OA are outlined below.

2.2 The Costs of OA

The costs of managing OA are relatively high in the present transition period. This is particularly true for countries like the UK that have taken a policy decision to support the gold route to OA through payment of APCs. Various initiatives have made attempts at calculating the costs of APCs and OA administration.

2.2.1 APCs

A number of UK funders have made a policy decision to support OA, achieved through payment of an APC in a pure OA or hybrid journal. There's a broad consensus that OA funded via APCs needs to offer a transparent and competitively priced market, but there are concerns that this isn't currently the case. A report by Bjork and Solomon,[3] published in March 2014, examined the rapidly developing APC market and identified options to support funders to ensure the APC market delivers transparency and quality services, and it offers value-for-money.

The report highlighted the rapid growth (approximately 30% a year) in gold OA and significant differences between the pure OA and hybrid OA markets in terms of cost, quality and service. Average APCs were found to be $1,418 for a 'non-subscription' publisher, $2,097, for an OA journal from a 'subscription' publisher $2,097, and for a hybrid journal $2,727. Through the report the funders aimed to stimulate discussion and debate on how all stakeholders can work together to ensure the OA market is competitive.

2.2.2 The Total Cost of Ownership

Jisc in conjunction with others such as Research Libraries UK (RLUK) and Society of College, National and University Libraries (SCONUL) negotiate with the main academic journal publishers, to limit the 'total cost of ownership'. This involves simultaneously negotiating with publishers on both journal subscription licenses and APC payments and to agree proposals that will offset APC payments against subscriptions. In order to model various offsetting schemes to support negotiations with publishers, Information Power, on behalf of Jisc Collections, collected data from 24 UK higher education institutions in 2014. All institutions agreed to the release of anonymised aggregated data that included financial information about both expenditure on journal subscriptions and expenditure on APC payments. A brief analysis of this data is available.[4] Some institutions went further and agreed to release detailed spreadsheets outlining expenditure. Releasing this data highlighted the scale of expenditure on APCs and helped to add to the debate about hybrid OA publishing.

2.2.3 Administration and Compliance

A report 'Counting the Costs of Open Access'[5] released in November 2014 by London Higher and SPARC Europe highlighted the significant costs associated with the administration of OA in the current environment. According to the report, in 2013–2014 the sector spent nearly as much on administering the RCUK OA policy (£9.2 million) as it did on paying APCs (£11 million). The report put the cost of meeting the deposit requirements for the next REF at an estimated £4–5 million. The report also outlined the compliance burden associated with the administering 'gold' and 'green' routes to OA and noted that:

- Making an article OA through payment of an APC (the 'gold' route) takes 2 hours or more, at a cost of £81.
- Making an article OA through self-archiving in an institutional repository (the 'green' route) takes just over 45 minutes, at a cost of £33.

The majority of costs were found to relate to staff time spent on policy implementation, management, advocacy and infrastructure development, although it's clear that as processes become more embedded there are opportunities for greater efficiencies over time. It's important to note that in spite of the costs, none of the respondents questioned the principle of increasing OA to their research outputs.

Each of these initiatives has relied on authors, funders and higher education institutions working collaboratively, sharing ideas and information to enable greater transparency and contribute to greater efficiencies. The move to OA demands significant changes to workflows and the development of new digital infrastructures, changes that take time to implement and cost money, but these changes are essential developments on the road to OA.

2.3 The Opportunities for OA

2.3.1 Collaboration

OA remains a rapidly evolving area but this presents opportunities. By working together across disciplines as an OA community, stakeholders have the opportunity to address issues associated with OA management and to influence change. Collaborative arrangements involving organisations such as Jisc, RLUK, the SCONUL and the Association of Research Managers and Administrators (ARMA) are common. The Jisc OA good practice pathfinder[6] projects are investigating what works best in implementing OA and developing shareable models of good practice. These institutions indicate what can be achieved with varying levels of research base, finance and human resource.

2.3.2 Metadata and Standards

Information about OA publications is currently held in a variety of systems and there's a real need to enable greater interoperability by improving metadata and standards. A significant amount of work is ongoing. This includes RIOXX[7] which is a metadata profile allowing institutional repositories to share information about OA research papers and their compliance with funder policies, and should be CASRAI-UK not CASRIA-UK[8] which aims to identify opportunities to align common terms and vocabularies to support OA reporting.

2.3.3 Licensing

One of the most relevant means of ensuring that research and information is accessible to everyone is to employ the proper licence. Licensing issues, to date, seem to account for one of the greatest barriers to complying with OA policies. Part of the problem is a general confusion over which licences are to be used, and some publishers' websites are not particularly clear in explaining what authors need to do in order to comply with a policy. Whereas RCUK emphasises that the CC BY licence must be used in order to comply with their policy, HEFCE takes a slightly more relaxed approach: 'We [HEFCE[9]] have not pushed for strict rules on licensing, but we recognise the benefits of more permissive licensing in providing more efficient and automated access to research, and we want to reward institutions that enable these benefits’. Thus, the main thrust of the policy is not to strong arm institutions and researchers, but to underscore that there is a public value in making an article OA and there is also the potential for reward if processes are put in place that enable OA to happen. Therefore, the success of OA is placed squarely on the shoulders of institutions and researchers to become more informed about what needs to be done, and if they do so, they stand to benefit both directly and indirectly.

2.3.4 Workflows

Another means of ensuring that OA happens in the best possible way is to ensure development of workflows to support the publication process. Many universities have developed efficient strategies, including creating working groups which then disseminate information about requirements at an institutional, faculty and school level. This can often result in a huge increase from academics enquiring whether their work can be made OA via the institution’s publication funds. This increase illustrates an even greater need to make sure the processes are as streamlined as possible and that there is the necessary support within institutions to make it all sustainable.

One of the best ways of ensuring efficient workflows is to get the Finance Department on board as early as possible and to communicate regularly when it comes to managing funds and paying for APCs. Joining up work with Finance would mean that the delays that occur when trying to get a publication paid for would be significantly reduced.

2.4 Research Impact

Kevin Dolby from the Wellcome Trust presented a report at the 6th Conference on Open Access Scholarly Publishing on September 17–19, 2014. His talk was about 'OA Publishing Community Standards – Article Level Metrics: A Funder's perspective'. One of the key points that he made was that availability of the published articles was vital to increasing the ability to measure the impact of the research. Another measure is citation, and one of the strongest examples he gave was that the article 'PHENIX: A Comprehensive Python-Based System for Macro-Molecular Structure Solution' was published in *Acta Crystallographica*, an OA, as well as hybrid OA journal, and was cited 2904 times, proving that making a publication OA can have a significant result in more citations, which in turn affects the academic's potential for more research and promotion. Although OA does not necessarily guarantee increased citation rate, the fact that there is evidence to suggest that it can increase them and that it can contribute to the improvement of peer review, it would seem that the arguments for OA are quite strong.

All that said, even those promising statistics show us that much still needs to be done, and that is not simply trying to get academics on board with either the carrot or the stick. Their concerns are many, and they are not simply about control over their research and where they publish, although those concerns are still significant. In the name of academic freedom, no research libraries or funding councils want to be perceived to be telling researchers what to do or where to publish; that said, many academics do point out that the push for OA has created some bureaucratic loopholes that would seem only to benefit publishers, and these lacunae need to be addressed and corrected.

Although with all publications in all fields, there is always a green option, the ability to self-archive the article in the institutional repository upon acceptance, there remains a great deal of confusion regarding what 'date of acceptance' actually means and which version can be placed in the repository that does not violate licensing or copyright.

Therefore, aside from the actual costs of paying for the APCs in order to get an article accessible to everyone, there is that additional cost of time: if there is an embargo period whereby the article cannot be made OA, then the arguments for OA increasing citations and impact are potentially severely curtailed.

OA clearly presents opportunities to raise the visibility and profile of the institution, to promote research outputs more widely and effectively, and to provide a better return on investment for funders. Academic research needs to remain vital and cutting edge if it is going to benefit humanity on a global scale. Although it is true that if a general member of the public wants to have access to an article, a very easy way is to write to the author and ask for a copy, that doesn't take into account that research which the public has paid for remains behind paywalls. Even many academics have had the experience of being published in a journal which their own university library does not subscribe to which ostensibly means that they, themselves, do not have access to their own article.

Although there are actual financial costs for OA, over and above the costs that cover staff and time, questions surrounding cost over price are important to ask when attempting to determine what the overall benefit of OA will be. Much has been done since the movement began in the 1990s, and the opportunities to institutions, researchers and funders are manifold if a truly collaborative atmosphere can result. Carrots and sticks remain the tools most often used to encourage engagement, but the true goal is a sea change, helping all key stakeholders understand the benefits that can come about – financial, research, engagement, collaboration, career promotion, policy strategies and access, as well as the potential for reinvestment back into innovation and technology.

[1]http://www.researchinfonet.org/wp-content/uploads/2012/06/Finch-Group-report-FINAL-VERSION.pdf

[2]http://www.hefce.ac.uk/media/hefce/content/pubs/2014/201407/HEFCE2014_07.pdf

[3]http://www.wellcome.ac.uk/stellent/groups/corporatesite/@policy_communications/documents/web_doc

[4]http://figshare.com/articles/Analysis_of_Jisc_Collections_APC_data/1061427

[5]http://www.researchconsulting.co.uk/wp-content/uploads/2014/11/Research-Consulting-Counting-the-Costs-of-OA-Final.pdf

[6]http://openaccess.jiscinvolve.org/wp/pathfinder-projects/

[7]http://rioxx.net

[8]http://jisccasraipilot.jiscinvolve.org/wp/

[9]http://www.hefce.ac.uk/media/hefce/content/pubs/2014/201407/HEFCE2014_07b.pdf

CHAPTER 3

Creating Opportunities Through Security

Andrew Cormack, Jisc

This chapter considers the complex information security challenges posed by the strategic objectives of research and education organisations. New technologies and techniques for accessing and processing information can assist by creating new ways to work safely and effectively. Organisations that help their users select and adopt appropriate tools and behaviours for key services and data will be best placed to benefit from new opportunities such as mobile and cloud computing, big data, e-research and remote learning.

Keywords

Security; opportunity; cloud; BYOD; e-research

3.1 Understanding Security in Research and Education

Research and education make highly complex, sometimes contradictory, demands on information and information systems. Researchers must handle information that is commercially, legally or ethically sensitive; participate in national and international collaborations; and engage in public discussion and dissemination of their work. Students need to access course materials, discuss with teachers and peers and perform assessed work irrespective of time or location. Research and education have always taken place wherever and whenever thinking occurred: if opportunities are not to be lost then information and systems that satisfy all these requirements must be there too.

The dependence of research and education on information, and the richness of that information, inevitably creates risks. Information may not be accessible when needed; its accuracy may not be known; or it may be disclosed to those who should not see it. Proportionate measures to protect key systems against these security risks – availability, integrity and confidentiality – are essential for research and education to be conducted reliably and safely. Risks exist independent of format: for centuries researchers have used codes to protect their discoveries against disclosure! The move to digital information may not only alter the risks but also creates new opportunities to address them.

In fact research and education organisations were early adopters of many of the ways of managing information risk now being discovered by the commercial world. Most of our activities would be impossible without them. As a recent SANS report (Marchany, 2014) notes, we have long presumed that staff and students will use their own computers for work. We routinely segment our internal networks, systems and policies to facilitate access while maintaining the appropriate level of performance, integrity and confidentiality for each activity. More than 20 years ago we recognised the importance of effective incident response in managing risk. Remote and mobile accesses are essential for many of our courses, staff and students.

With corporate and home users now adopting similar approaches a growing number of commodity products are including support for them. Remote access and the use of personal devices will become habits or expectations of our users. However, the needs of research and education remain particularly, perhaps uniquely, complex so we still need to plan our human and organisational processes to make best use of these opportunities. New demands, for both greater protection of and wider access to research data and for both increased availability of and increased income from teaching, continue to challenge us to define and implement appropriate security to achieve our organisations’ strategic objectives.

3.2 New Ways of Being Secure

Changes in technology and individuals' use of it create opportunities to provide security in new ways. A key development is the increased performance of both networks and client machines: by some measures a modern tablet is faster than a Cray-2 supercomputer! Digital encryption, once the preserve of nation states, is now used routinely and almost invisibly by every online consumer. This lets our devices communicate securely with servers no matter whether they are on the same campus network or on the other side of the world; locally stored information can be encrypted as a matter of course, even on a device as small as a smartphone. For applications or information where local storage is inappropriate, the wide availability of fast network connections lets services provide access via remote terminal protocols so that information remains on the server and only screen images are transmitted to the client.

Together these capabilities, by making the distance between client and server almost irrelevant, may permit a better balance of security measures for both. Servers can be placed in more physically secure locations if they no longer need to be close to clients: client systems can give more priority to users' needs once they are no longer bound by specific security requirements imposed by servers. New technologies give more flexibility where and how to implement the security we require.

Individuals have become used to carrying their own digital devices, which are not shared with others. This habit makes strong, two-factor, authentication more practical since this relies on a token or device being held by a single owner. Many people already carry the token or phone that they use to log in to their online bank accounts. Convenient, low-cost authentication of the same quality is now possible for those of our services and information that require it.

For decades, research and education organisations have benefited from staff and students using their own computing equipment, whether at home or on the move. Most mobile devices can now be wiped remotely, providing greater protection for both owners' and organisations' information when the device is lost or stolen. While businesses still discuss whether to allow what they have christened Bring Your Own Device (BYOD), education recognises it as essential. Since users will connect their devices to any service that is available on the network, we should help them use those devices safely to our mutual benefit. Additional measures such as device authentication or remote terminal access can be used by services that need more control. We should treat BYOD as the default, not the exception.

On the server side, virtualisation can provide systems that are more flexible and easier to manage than traditional server boxes. Virtual machines can be configured to more precisely match the security requirements of each application; the virtualisation layer offers an additional opportunity to implement security measures though it may also present challenges for security monitoring tools. Virtualisation enables new ways to deliver services including public clouds whose physical security and ability to cope with peaks in demand exceed anything the organisation can itself provide.

Each tool offers a different balance of benefits and risks. For example remote access makes information more available to users but also makes them more responsible for its confidentiality. Different tools will be appropriate for different information and services. To find the right balance organisations should consider the various options, including how a process is done now, and assess which brings the organisation closest to its desired risk profile. As has always been the case, for information on paper and in digital form, one of the largest risk factors will be how users behave: whether they follow the system or try to get around it. Approaches that match their reasonable expectations of how to work are most likely to deliver the intended results.

3.3 Designing Security for Research and Education

Long ago, the goal of digital security was to replicate the organisation's physical perimeter: 'inside' was considered safe, 'outside' hostile. However, research and education are rarely constrained within physical boundaries and almost never by the physical extent of university or college premises. Our organisations need highly porous perimeters: teaching and research require us to welcome students and guests, administration would grind to a halt if staff could not perform their duties while at overseas conferences. Both physical and digital securities require a more sophisticated model.

A key observation is that, like our campuses, our campus networks are little different from the (Internet) outside world. We may know more about what happens there and be wholly responsible for keeping things running, but we should regard local networks and the Internet alike as critical to our operations and likely to contain things hostile to our interests. Instead the significant borders, where security requirements change, are within the organisation. Some activities, such as those involving student or personnel information, should prioritise confidentiality; some, such as websites and repositories, need maximum availability; some, such as software testing, may present a threat to the organisation and need their own digital containment. These different information security zones sometimes match physical spaces – sensitive research may be required to take place in a designated physically secure location – but more often they extend to wherever the person performing a particular role happens to be.

This means that many people will cross, during their working day, between zones where different information security requirements apply. They may not even need to move, just open a different document. For these people, who may well be the majority of our users, the divisions protecting critical services and information can no longer be implemented just by physical and digital borders, they must be part of behaviour too. Research and education organisations that need the flexibility that comes from allowing users' devices into the office or making services available at home and in cybercafés must help and trust users to know when, and when not, to exercise that flexibility.

This is nothing new: information security already depends on users knowing which matters should not be discussed in public places or shared with colleagues. Organisations should help their users develop the right instincts about how to behave both on- and offline. For most activities there will be a sufficiently secure approach, perhaps using some of the new technological possibilities, that the organisation can provide or recommend. When users come up with new solutions, consider whether they are secure enough to adopt, can be improved or whether an alternative is better. And don't, whether by deadlines or inadequate provision, force users to act unsafely.

In the open environment that research and education require, smart, informed, motivated users – supported by appropriate policies and technologies – should manage risks more effectively than technology that blindly attempts to prevent unsafe actions. Inflexible or inappropriate technology can prevent us meeting our objectives or even encourage unsafe behaviour in order to get the job done.

3.4 Creating Opportunities Through Safe Working

Education organisations no longer have a monopoly of technologies or information: many of the systems that create new opportunities and risks are already in users' hands or available at the click of a mouse. The traditional perception that the IT department 'does' security for everyone else is neither appropriate nor acceptable. Instead information services should identify various packages of policy/technology/behaviour that provide consistent protection for information; information owners then decide, based on the organisation's risk assessment and their knowledge of the information, which package they and users of their information need to adopt.

This model has been likened to a pomegranate, with seeds representing different security zones within the organisation. As already discussed, zones must be implemented by a combination of policy (e.g. how to handle sensitive information), technology (e.g. firewalls) and behaviour (e.g. not taking papers out or bringing insecure devices in). Some zones will extend outside the organisation's physical and network perimeter: to data centres and clouds, to remote and mobile workers and to partner organisations. Encrypted virtual private networks and strong authentication can extend the technical perimeter: authenticated users must themselves extend the policy and behavioural ones. To ensure that zones provide consistent protection it's helpful to consider how a malicious individual or organisation would most easily gain access to protected information, then assess whether those weak points are strong enough.

Information services are unlikely to be the right people to decide which information needs to be protected by which kind of security zone. Instead they should help information owners identify key information and the best way to satisfy its organisational requirements. Information owners know most about their information and the risks it is exposed to; they will also experience most directly the practical requirements of working with it. Information services should advise on how best to meet those requirements and ensure that the measures chosen are consistent. When new research or education opportunities arise, a menu of prepared security packages with policy and technology ready to support them will let the organisation respond quickly and with confidence.

In the digital future of research and education, appropriate security will enable organisations to make the most of new opportunities without incurring unacceptable risks for themselves, their people or society. Information services should identify and prepare relevant new security approaches created by changes in technology and our use of it, while information owners and users recognise and adopt the opportunities those approaches create. Successful organisations will achieve the greatest benefits by helping people work safely, not just trying to stop them doing unsafe things.

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CHAPTER 4

Open Data

Higher and Further Education Stepping up to the Challenge

Rachel Bruce and Andy McGregor, Jisc

It has been impossible to avoid open data in the last few years. This has been driven by support from governments the world over and innovative work in the UK from organisations like data.gov and the Open Data Institute. Despite some strong examples, higher and further education is not moving as quickly as the government. Although the UK government is making great strides, there is not yet compelling evidence on the impact of this effort. So higher and further education is left with the question: is this something we should seek to address urgently or is it more prudent to wait until undeniable evidence of impact is available before deciding to dedicate significant effort to exploiting open data?

Keywords

Open data; UK government; higher education

Defining open data is a non-trivial task, the definition needs to encompass how data is made available and how it can be used. Anyone with any experience with any of the open clans will know that open comes in many guises. The Open Knowledge Foundation gives a full definition of what open means for data (http://opendefinition.org/) but it also gives a succinct version:

> *Open data and content can be* **freely used, modified, and shared** *by* **anyone** *for* **any purpose**

What this means in practice is that data that was traditionally managed and used within an organisation is made available via the web for people to examine and exploit. The range of data that this could cover is enormous, from A-road traffic data (http://data.gov.uk/dataset/congestion_on_local_a_roads) all the way to enterprise zones (http://data.gov.uk/dataset/enterprise-zones), and via further education and skills inspection outcomes (http://data.gov.uk/dataset/official-statistics-further-education-and-skills-inspection-outcomes) and student loans (http://data.gov.uk/dataset/student_loans).

At its most basic level making data available can be via a pdf, but real benefits only start to occur once machine readable formats are used. Machine readable means anything that can be processed by a computer, this can be a simple spreadsheet but the really interesting use cases and benefits are realised when Linked Data is used. This data format focuses on the relationships between items and enables software developers to produce applications that can do more useful things with the data. It also makes it easier to connect different data sets to produce innovative new uses.

4.1 Why It Matters

Making data available openly is not free the preparation of the data and the provision of it cost time and effort. So it is interesting to ask why, in an era of austerity, has the UK government pursued an open data approach with such vigour. Unsurprisingly it is for hard practical reasons rather than anything ideological. Open data offers many benefits, the most compelling are:

1. *Transparency*: Many organisations have a duty to their stakeholders to show what they are doing and how. Open data enables this directly by allowing data literate stakeholders direct access to the data and indirectly by enabling people to build applications that allow the layperson to explore the data via websites, visualisations and applications.
2. *Efficiency*: Engaging in open data may produce efficiency savings. Savings could come from refining the production and management of data across an organisation, for example by linking up previously separate data sets that contain duplicate items. Another possibility is reducing the amount of time spent helping stakeholders by enabling them to find and use the open data whenever they need it.
3. *Innovation*: Opening data up in machine readable formats allows entrepreneurs or amateurs to use that data to build new applications that people may find useful. This could be done by using a single data source in an unexpected way or by connecting previously unrelated data sets to support a new type of use. Rufus Pollock, the president of the Open Knowledge Foundation, summed this up as: 'The best thing to do with your data will be thought of by someone else' (http://rufuspollock.org/misc/). As well as producing economic value from this new use of the data it can also illustrate new possibilities that can influence the direction of an organisation.
4. *Participation*: If data is transparent and delivered via innovative applications, this can lead to greater involvement from stakeholders in the work of an organisation. This is most useful in government where participation is desirable on a number of fronts. But other organisations may find participation from certain types of stakeholders, for example, alumni to be desirable. This benefit may be challenging to achieve because of fears that lack of technical and data analysis skills may prevent all but a few engaging in detail and may produce inequalities between the data haves and the have nots.

These benefits are not only theoretical, but a number of studies have looked at the economic value of engaging in open data. CapGemini produced a report that estimated that opening government and public data had a direct impact of €32 billion on the EU27 economy in 2010 with a forecasted growth of 7% a year (http://www.uk.capgemini.com/resources/the-open-data-economy-unlocking-economic-value-by-opening-government-and-public-data). However, this may be an underestimate since a BIS report on the value of the Ordnance Survey open data predicts that by 2016 this data set alone will have increased Great Britain's GDP by between £13 million and £28.5 million (https://www.gov.uk/government/publications/ordnance-survey-open-data-economic-value-study).

Nearly all the examples we have used so far have come from the work of the UK government since they are not only the leading exemplar of open data in the UK but reports such as CapGemini's (*referenced above*) and the Open Data Barometer (http://www.opendataresearch.org/barometer) put them near the top of governments worldwide when it comes to open data.

This started in 2009 when open data was mandated across UK government departments. It continued despite the change of government in 2010 and that year (data.gov.uk), the website that collects open data sets (http://data.gov.uk/), was created. Five years later the site lists over 16,000 published data sets. Data.gov.uk uses a 5 star rating to judge how open a dataset is (http://5stardata.info/). The majority of datasets listed get a rating of 0 stars, which means they are unavailable or not openly licenced. But of those that are available, most are at level three and above which means structured data in an open format. There are over 350 apps on the site which deal with issues from flooding, to safe neighbourhoods to visualisations of where money is spent.

The government has been assisted in this work by bodies like the Open Data Institute (http://opendatainstitute.org/), who promote open data and engage developers and the Open Knowledge Foundation (https://okfn.org/) who built CKAN (http://ckan.org/about/), the software that data.gov.uk is built on.

At the moment government strategy is focused on the development of a national information infrastructure (http://data.gov.uk/consultation/national-information-infrastructure-prototype-document/purpose-nii) this will develop the work done so far and build a better documented picture of what data is available and how it can be used. This will make it easier to find data sets and reuse them in useful ways therefore increasing the benefits to be seen from this wealth of data.

So the UK is at the forefront of open data, it has a rich and diverse data collection and a detailed strategy for ensuring the full potential value of this collection is realised. If the benefits are sufficiently high to attract this level of effort from the UK government then should further and higher education be doing more to exploit open data?

4.2 Where Is Further and Higher Education?

While the government is ahead of the university and college sectors in the UK in terms of coordinated open data strategy and implementation it should be noted that much of the underpinning rationale and technology for open data originated in universities and research institutes. For example the invention of the World Wide Web by Sir Tim Berners Lee at Cern could be claimed as the birth of open data; and since this time academics, such as those at Southampton and the Open Knowledge Foundation, have continued to develop the concept. Open data and sharing has also been used in research for centuries. A fantastic example of open data reuse is that of Matthew Fontaine Maury a historian and oceanographer back in the nineteenth century who studied ship logs and metrological data; on the back of this data analysis he published a chart of the winds and currents that enabled sailors to speed up their course.

In the UK education and research sector as machine readable formats for open data became easier to implement Jisc supported early experiments in open Linked Data, and as part of this the Open University undertook the LUCERO (Linking University Content for Education and Research Online) project. They became the first UK university to open up their data making data sets, including course data, research outputs, open educational resources and administrative data available (http://data.open.ac.uk/). They were closely followed by the universities of Southampton and Lincoln. These developments have enabled the support of applications, for example at Southampton applications have been developed that include an interactive university map widget, a catering 'menu search' function, university telephone directories and apps making navigating open days easier. James Leeming the Retail Catering Manager at Southampton University says:

> *As a Caterer I am often quoting that 'I bake bread, I don't do IT!' we like to keep it simple and this is exactly what Open data does for us. We can use formats and software we are used to and manage up to date real time information. This will ensure we are keeping customers up to date with information that they want. There is more to come as well and in Catering we have designed our whole web site and marketing strategy around the Open Data technology, watch this space, Catering is catching up.*

[insert reference from the analysis of the value and impact of Linked Data – Jisc report]

In an attempt to provide a platform for all open data across UK academia Southampton University developed the data.ac.uk hub that acts as a single point of contact for open data from universities in a similar way to that of data.gov.

Opening up data of different types, including manuscripts and historical records, can enable text mining. The *Trading Consequences project* about Britain's reliance on overseas commodities in the 1800s has used text mining to explore thousands of pages of related documents for terms associated with commodity trading. Vast amounts of digitised historical records are available about the extent to which Britain relied on overseas commodities in the nineteenth century but despite this huge resource, and maybe even because of its size, the story is impossible to accurately track manually. Trading consequences has made sense of them and provided a visual analysis tool.

Big data is an area of significant interest to all fields of research, and *digital text mining* has created major efficiencies when comparing a vast number of documents, as well as unearthing new correlations and discoveries; we've seen this strongly in biomedicine as they deal with an ever increasing amount of research outputs, and now also in social sciences and humanities in initiatives like *Digging into Data*. The introduction of copyright exemptions for text mining for non-commercial research gives the UK a lead over many other countries. The only other country in the world that has a similar text and data-mining exception is Japan. Opening up data clearly lends itself to the advantages of text and data mining.

Citizen science is a trend that demonstrates how open data can accelerate research. One of the most quoted examples is Galaxy Zoo, in 2007 a data set of a million galaxies from the Sloan Sky Survey was opened up to all for analysis. The team were astounded when within 24 hours of the launch of the data set they received 70,000 classifications an hour. They say that 'In the end, more than 50 million classifications were received by the project during its first year, contributed by more than 150,000 people.' they received multiple independent classifications that tested the reliability of the classifications and the team have proved that the citizen participation was as accurate as a professional astronomers work. This data set has been of use to many researchers and it continues to be today.

Universities have also started to open up usage data. In a Jisc supported initiative universities experimented to test if they could use data in a similar way to that of big companies such as Tesco and Amazon. With the leading example from Huddersfield University, where they made their library usage data openly available, a small but significant development has taken place whereby better services can be offered to learners and researchers by using patterns of behaviour to inform personalised experiences, and also to correlate such data with student attainment. For example if a student isn't using the library they may be at risk of falling behind and the university can make an intervention to help to prevent their potential dropout. Jisc has worked with a number of universities to develop a prototype national service that brings data such as the National Student Survey, library usage data and other data sets together to help to inform data-driven decision-making.

The policy environment is supporting a move towards open data, for example research funders are encouraging openness, and the Universities UK (UUK) work on efficiency sees open data as something that can support more efficient sharing and reuse in various ways. However, despite this there is a long way to go, and if we look at the education and research sectors in comparison to that of the government it can be argued that these sectors are behind. It appears that there are pockets of excellent practice that have started to prove the benefits but these are not yet connected, and universities and colleges are not on the whole treating open data as a strategic direction. It is perhaps not surprising given the range of use cases and types of data that there are, and the diverse nature of universities and colleges. Coordination is challenging. Whilst it might be true to say that some of the benefits are a bit of a leap of faith the examples above do show that there are innovations that can come from open data.

So why should further and higher education take open data seriously? It is, we argue, for very similar reasons to that of the government.

Transparency is a driver, for example knowing what research funding has produced, or giving confidence of fee paying students with regard to curricular and courses. It may not be as obvious a case as it is to government but it is likely to become more important as the sector needs to demonstrate the way it goes about its business and contributes to the economy and society. Data about higher education is collected through bodies such as the HESA and UCAS, much of this data is available but there might well be more openness possible in support of further transparency.

Innovation is important, as well as innovation in research and learning there are collaborations to be exploited that open data can support. The Gateway to Research where information about the research funded by the UK Research Councils is made openly available on the web ensures that industry and small and medium enterprises (SMEs) know about publicly funded research and new collaborations can be forged. This also points to participation, open data can help to improve and widen participation – whether this is via citizen science or via the wider participation in education through open educational resources and MOOCs; essentially it increases the reach of the education and research sector.

The Diamond Review from UUK on efficiency in higher education considered open data and recognises that it goes beyond efficiency. There are work streams dedicated to open data that aim to encourage the exploitation of data in support of improved business processes and intelligence whereby administrative data can be better used to lower costs and improve processes; where open data can be used to improve student recruitment, choice and experience and where research management and reuse can be improved via openness.

One of the most significant areas in terms of policy is that of open research data, the Research Councils and other research funders are promoting this since openness can support research integrity by ensuring that results are verifiable; and reuse that drives new research findings. The sector is making advances here, but it is a challenge as culture needs to change and also technical infrastructure to support data sharing needs to be in place at universities and at a national and international level.

In order for education and research to grasp the open data nettle in the same way as the government sector there is a need to address a few central issues. These are:

1. A central and strategic driving force: this could build on the UUK efficiency work, the Open Data Institute and Open Research Data Condordat that is being developed between research funders and universities. For this to happen there will be a need for partnership working since a variety of stakeholders have important roles in the developing open data landscape.
2. There are technical foundations that can help open data to flourish; in particular the use of identifiers. This includes identifiers for data objects, for people, for organisations and for places. Identifiers enable connections, links and correlations to be made between different sets of data. Jisc is working with stakeholders on some related agreements, for example the use of researcher identifiers, ORCID (http://orcidpilot.jiscinvolve.org/wp/) or organisational identifiers such as ISNI (http://www.isni.org/). Alongside this data aggregations need to be coordinated, including data.ac.uk and the national research data registry that Jisc is developing.
3. Legislative barriers need to be overcome: there have been great strides

such as the Public Sector Information directive and the UK data and text-mining exception. However, there are still barriers, for example the legal deposit legislation still severely limits access to copies of the UK web archive.
4. Cultural change is required: this is perhaps the toughest aspect of all. Top-down initiatives are helping to drive change, for example data becoming more prominent in research assessment but cultural change is greater than this. There is a need for a data skilled workforce, for all to understand the benefits and be convinced of the rewards of open data so they will participate.

It is hard to escape the conclusion that there are great benefits here for higher and further education if we want to seize them. There are significant barriers but the work of data.gov.uk has paved the way. Further and higher education is full of people with diverse skills and innovative ideas so we are well placed to surmount those barriers. We think that Jisc's role as a national body also offers opportunities for producing some of the technical infrastructure and support that would need to be reliably and sustainably provided for open data to flourish. When you think of the rich and growing data sets produced by people working in further and higher education and the new and exciting innovations that it could support it seems the answer for the education and research sector is to step up and grasp the nettle of open data.

CHAPTER 5

Enhancing the Digital Student Experience

Sarah Knight, Jisc

This chapter discusses how universities and colleges are enhancing students' digital experiences. Technology is changing at a fast pace and hence staff and students are required to continually develop their digital capabilities in order to fully realise the affordances of technology in supporting learning, teaching and assessment. Working in partnership with students to engage them fully in the development of the digital environment is critical so as to gather a better understanding of current and future needs in relation to the digital. A digital environment which not only supports the requirements students currently have, as well as meeting future needs, will ensure students have the necessary employability skills required to thrive in a digital economy.

Keywords

Digital student experience; technology enhanced learning; digital literacies; student partnership; learning; teaching; assessment; curriculum design; technology; practice; digital capabilities

For today's students, the quality of the learning experience is even more important as students take more ownership of their learning. There have been significant changes in both the technology and educational practices of staff and students over the past 10 years. Attention is often placed on the technology and its advances but in this chapter, pedagogical principles, practices and the skills staff and learners require take precedence. Advances in technology and the availability of digital content together with innovation in rethinking the dynamics of the classroom practice have resulted in a more active and engaged experience for students. There are, however, still significant challenges ahead to ensure that the workforce has the necessary digital capabilities to fully realise the potential of the digital age. Some questions which this chapter addresses include:

- How are colleges and universities responding to students' changing expectations of their digital environment?
- What experiences at university or college prepare students to flourish in a digital world?
- What are institutions doing to engage students in dialogue about their learning environment and to gather intelligence about their changing

needs?

5.1 What Is Changing?

The environment of further and higher education is changing in response to economic pressures, government policies and changing behaviours influenced by greater ownership of new technologies. In turn, this is encouraging institutions to review key aspects of their provision and to reassess what is delivered, to whom and in what ways. The quality of the learning experience is still the prime consideration, but our understanding of what constitutes quality has grown to recognise the importance of aspects such as inclusive learning, working in partnership with students and preparing students for future employment. Colleges and universities need to engage more fully with employers to prepare graduates to meet the evolving needs of industry and fulfil workforce development needs. Increasing the authenticity of learning better prepares learners for the workplace, builds learner confidence and develops skills valuable to employers.

Institutions recognise the importance of technology in supporting their core business and ensuring that their students have access to appropriate technology, digital content and online administrative systems to support their educational experience. The UCISA (2014) 'Survey of Technology Enhanced Learning for higher education in the UK,[1] states that '*enhancing the quality of learning and teaching is consolidated longitudinally as the primary driver for considering using technology enhanced learning* (TEL)'.

The mass appropriation and rapid uptake of new technologies is changing behaviours. It is common for us to be able to communicate and to access, process and send information without being tied to any one location. Online learning is one option in a wider array of learning opportunities that we choose to blend with others to build models of learning that meet our personal circumstances. The Educause Learning Initiative/New Media Consortium 2014 publication, The Horizon Report: Higher Education Edition[2] identifies that '*social media is changing the way people interact, present ideas and information, and judge the quality of content and contributions. More than 1.2 billion people use Facebook regularly according to numbers released in October 2013; a recent report by Business Insider reported 2.7 billion people – almost 40% of the world population – regularly use social media*.'

5.2 Who Owns the Technology?

Technologies are moving from institutionally controlled systems (e.g. the virtual learning environment) to integrating institutional services and technologies with those which students own and control, for example, social media tools and mobile applications.

The rise in ownership of personal technologies combined with a growing awareness of their educational potential is encouraging more collaborative relationships with students: educators and students are jointly working through the implications of introducing new technologies and designing new approaches that better meet their needs. The NUS (2014a) report, Radical Interventions in Teaching and Learning, suggests that '*in order for universities to foster more inclusive learning environments, we believe that students must be empowered as active and participatory agents, not as mere consumers, so that they can articulate their own conceptions of what makes good learning environments, and work in partnership with academics and administrators to realise these conceptions*'.

The ease of access to new technologies means that some students can afford newer-specification devices than colleges and universities can supply. Moving away from fixed equipment to open data systems and access to institutional platforms requires alterations to infrastructure, policies and estates to protect key systems and comply with legal safeguarding and personal safety requirements – safeguarding being a key priority for further education, which accommodates learners from age 14.

5.3 How Is Technology Enhancing the Curriculum?

Curricula being constrained by dated institutional processes and practices are evolving to meet the changing needs of students and employers, to reflect new audiences and new approaches to learning. Considered use of technology as part of the curriculum design process can help institutions to:

- develop new solutions to address organisational, technical and educational issues;
- communicate in new ways with stakeholders to facilitate discussion and collaboration;
- access, record and capture information to inform your curriculum design;
- improve access to guidance for those designing and describing curricula;
- model, test and refine new approaches in curriculum design;
- improve communication flows both internally and externally;
- provide 'single-truth' sources of information that are accurate and can be interrogated and analysed to suit multiple purposes;
- develop effective and agile validation processes that are more responsive to employer and community needs;
- increase consistency both in terms of the learner experience and quality assurance;
- develop more efficient administrative processes.

Jisc's Enhancing Curriculum Design with Technology guide (2012a)[3] offers valuable guidance on the role of technology in supporting curriculum design with examples of institutional practice.

There is more embedded and integrated use of technology in the curriculum moving from using technology to simply replicate what staff and students currently do in a non-digital environment, to offering more engaging and authentic learning opportunities. The NUS (2014a) report 'Radical Interventions in Teaching and Learning', states, '*it's rather cliché to say that technology is transforming the way we interact with and communicate knowledge and ideas. But it is not the technology in itself that is transforming education and society; it is, rather, the creative ways in which people are using technology to educate and drive change*'.

Closed, institutionally owned content is giving way to open access with educational resources being more widely and freely available, giving students choices over where, when and how they study. In addition, students can benefit from the growing opportunities MOOCs present. Traditional lectures with didactic content delivery are evolving into flipped classroom approaches where students work together collaboratively on authentic and real-world activities developing the necessary employability skills to live, learn and work in a digital society. This change is being reflected in the design and development of physical learning spaces to enable technology to be seamlessly integrated, as illustrated in the institutional case studies in the Jisc Learning spaces guide[4] Students value the importance of the physical space within institutions as much or if not more than the virtual, as being the social space they can connect with their peers, have access to their tutors and supporting advice and guidance.

5.4 How Is Technology Enhancing Assessment?

A Jisc (2012b) review of the assessment and feedback landscape[5] revealed that this is an area where traditional practices predominate and remain 'stubbornly resistant to change'. With students expressing less satisfaction with assessment and feedback than with any other aspect of their learning experience[6] change is both desirable and necessary in many areas. Universities and colleges are increasingly revising their learning and teaching strategies to encompass learning, teaching and assessment, but there are still many examples where responsibility for assessment and feedback is devolved to individual faculties, schools and departments leading to inconsistencies in approach. There is a growing body of evidence that highlights the active engagement of learners in assessment and feedback as the critical factor in enhancing learning, together with a principled approach. A shared set of educational principles can provide the strategic steer that has previously been missing in institutional approaches to assessment and feedback. Jisc (2014e) has produced some valuable guidance[7] on supporting institutions with changing their assessment and feedback practices.

Electronic management of assessment (EMA) (2014g) is a growing area of importance[8] for institutions in realising the benefits that technology can offer in terms of supporting efficiencies in the assessment of student work and improving the quality of feedback. Although there are recognised challenges in this area, Jisc is working with institutions and key sector bodies to address the barriers to the take-up of EMA.

5.5 How Are Students Engaged in Developing the Digital Student Experience?

The importance of capturing and understanding students' expectations and experiences of using technology as part of their educational experience is critical if universities and colleges wish to meet and support their requirements relating to the digital. The Jisc Digital Student project (2014d)[9] is currently researching students' perceptions and their expectations in the use of technology across higher and further education and skills, and offering guidance for institutions on how this can inform strategy and policy developments in this area. This study is offering valuable insights for institutional leaders on developing their future strategies and provision in order to further develop a digitally enabled environment for their current and future students. Helen Beetham, lead researcher on the Digital Student study (2014f), in her recent blog post[10] on 'Students' experiences and expectations of the digital environment', reports that arriving students' expectations vary a great deal. School, national culture and family background play a part, along with the subjects that they choose to study. A few have very limited experience of Information and Communications Technology (ICT) at all. But some expectations seem to be widespread namely the availability of robust and ubiquitous Wi-Fi across campus locations; the ability to easily to connect their own devices to the university network, and access personal/social web services; and continued access to institutional devices, especially desktop computers with relevant software for their use.

Beyond these basic 'hygiene factors' there is a more varied picture. Students find different ways of working with technology. They need a flexible environment that lets them experiment, learn from each other and create their own blend. But many of their most valued experiences – specialised skills such as design, data analysis, reference management and journal searches – are formally learned as part of the curriculum. This means that the confidence of teaching staff has a strong impact on students' satisfaction with the use of technology. This highlights the importance of supporting staff with their continual development of professional practice in the use of technology and how this goes beyond the functional skills but relates to the appropriate and effective use of technology in their teaching or research. So general expectations are rising, but students are still unclear about how the technologies they use at university or college can help them to succeed.

Colleges and universities have recognised that they need to improve their strategies and approaches to engaging students in an ongoing dialogue around the expectations and experiences of technology and the digital environment. Working in partnership with students on digitally related projects enables both staff and students to have a shared understanding of how the digital environment can better support the learning experience. The NUS (2014a) report, Radical Interventions in Teaching and Learning[11] states, '*in order for universities to foster more inclusive learning environments, we believe that students must be empowered as active and participatory agents, not as mere consumers, so that they can articulate their own conceptions of what makes good learning environments, and work in partnership with academics and administrators to realise these conceptions*'. The Jisc (2014a) Change Agents' Network[12] actively supports a community of practice of students and staff working in partnership on technology-related innovation projects and fosters the sharing of best practice.

5.6 What Are the Challenges Facing Institutions?

The complexities and interlinked nature of the challenges faced by institutions in embedding effective use of technologies require leadership at a senior level to champion the digital student experience This leadership should be introduced as part of a holistic and strategic vision with due consideration to the support mechanisms necessary to engage staff and students and make the introduction of technologies successful.

How well UK universities and colleges are responding to the needs of their students is fundamental to their ongoing success and continuing position in the global education market. The importance of addressing the ongoing development of digital literacy skills of students and staff,[13] the support for senior managers in managing change and developing strategies for innovation in a resource constrained environment, engaging employers in a more active role in the design and delivery of the curriculum and ensuring institutional assessment and feedback practices and processes are robust and effective. Underpinning this is working in partnership with students to transform the digital student experience where, '*partnership should not be seen as a set of discrete exercises or engagement mechanisms, but rather a way of framing the culture of the community that exists within a higher education provider*', The Principles of Student Engagement[14] (NUS, 2014b).

5.7 Principles for Developing an Enhanced Digital Student Experience

In order for universities and colleges to fully realise the vision of a digitally enabled student experience which offers an enhanced learning experience for all students, there are seven key principles which institutions need to address. This guidance (2014c) has arisen through the extensive consultation process[15] which the Jisc Digital Student project conducted in 2014.

1. **Preparing and supporting all students to study effectively with technologies**. When considering the student journey with digital technologies institutions need to consider all aspects from pre-sessional/pre-induction to post-graduation/alumnus status. Students do not have clear ideas when they arrive at university or college about how digital technologies can support their studies or how they may be important in their lives beyond university or college. Institutions need to help students develop those ideas.
2. **Delivering a relevant digital curriculum which offers students opportunities to gain confidence and competence undertaking authentic tasks relevant to the subject(s) they are studying**. This means that although there are generic practices that all students should acquire - such as online research and communication, digital presentation and identity - there are many ways of being a successful digital student. Students will look to subject specialists to guide them in the skills and practices they need.
3. **Delivering an inclusive student experience, using digital technologies to overcome disadvantage**. Digital technologies can help students overcome some of the barriers that may get in the way of their learning. Universities and colleges now have a legal duty to support access for all, and assistive technologies have an important role to play in that. However, not all solutions should focus on individuals identified as having special needs. Accessible design and inclusive assessment are approaches to learning for all. They do not make special provision for some learners but aim to provide all learners with materials that suit their preferences, and with assessment tasks that allow them to demonstrate what they can do.
4. **Delivering a robust and flexible digital environment where digital environment means both the digital infrastructure that students use and the spaces and places of the institution that are enriched with digital capacity**. The digital environment needs to be robust and secure but also flexible and open to innovative uses. Digital spaces are important opportunities for building student loyalty and enabling students to realise what is available to

them as part of the university or college offer.

5. **Developing coherent policies for 'bring your own' devices, services, and data. Policies need to be developed from the standpoint of how support will be re-profiled to focus on general digital capability rather than the use of mandated systems**. 'Bring your own' may be a threat to inclusivity and parity of experience. Institutions need to consider how students without good access or skills could be identified and supported.

6. **Engaging in dialogue with students about their digital experience and empowering them to develop their digital environment**. Students are often surveyed about their satisfaction with institutional services including IT, TEL and digital information/library/learning resources services. To an increasing extent, digital issues are also included in surveys about student satisfaction overall. However, students do not often feel that these surveys fully reflect their views or that feedback is acted on effectively. An approach that is oriented on finding solutions – in dialogue and/or partnership with students– allows students' own ideas and expertise to be brought into play, in a way that is not possible when the focus is on customer satisfaction.

7. **Taking a strategic, cross-institutional approach to developing the student digital experience for the future**. Ownership of the 'digital student' agenda falls across many roles and departments. Universities and colleges need to find ways of bringing key stakeholders together – with students – to ensure responsibility for developing the digital experience is embedded.

These seven principles are key components of a successful student experience and where technology can offer enhancements and efficiencies. A digital environment which not only supports the requirements students currently have, as well as meeting future needs, will ensure students have the necessary employability skills required to thrive in a digital economy. Further guidance to support colleges and universities in implementing these principles is available from the Jisc guide (2014h) Enhancing the student digital experience: a strategic approach[16]

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CHAPTER 6

International Collaboration and the Changing Digital World – Opportunities and Constraints

Matthew Dovey, Jisc

The remarkable growth in the power of IT and computer systems over the last few decades has had significant impact on the types of research problems that can be addressed, and on how research can be undertaken in distributed and cross-disciplinary teams. These new types and methods of research are supported by various technology e-infrastructures (network, computational and data) and online research environments. This chapter discusses these new technologies and the changes, potential and challenges, which these provide to the research community and practice.

Keywords

International collaboration; data; digital world; modelling; simulation; virtual research environments; video conferencing; high performance computing; high throughput computing; grid; cloud; e-infrastructures; open science; open data; virtual reality

6.1 Introduction

The remarkable growth in the power of IT and computer systems over the last few decades has had significant impact on both the way research can be undertaken and the nature of the research problems which can be addressed. In the book '*The Fourth Paradigm: Data-Intensive Scientific Discovery*' (Hey, Tansley, & Tolle (2009)), four paradigms shifts in the scientific research process are outlined: experimental, theoretical, computational and data-driven. The latter two have been direct results of the explosion in computational power and digital storage.

Growth in computing power has permitted more complex, sophisticated and accurate mathematical modelling and simulations: complex mechanical, physical and electronic designs can be built and tested long before going anywhere near a fabrication plant; chemical and medical experiments can be conducted 'in silico' rather than in 'wet lab.s' real-world events such as climate or traffic flows can be modelled and predicted with increasing accuracy.

Data can be generated from an increasing range of devices and simulations, but now can also be collected from an increasing range of devices (such as sensor networks and devices, crowd-sourcing, social networks). Moreover, data can be collected within increasing accuracy and increasing granularity. Advances in computational power, network speeds and new software algorithms, enables data mining to discover new correlations within this data and to identify possible relationships between data sets which could not previously have been compared.

It is evermore common that extreme specialism is need in order to push the envelope of our current knowledge in specific disciplines. Research is typically undertaken by cross-disciplinary teams of specialists in both academics and technologists. New communication technologies allow these teams to work together even though they may be as dispersed geographically as in their specialist areas.

6.2 Research E-infrastructure

In may come as no surprise that this potential comes with significant challenges. Whilst science and innovation are recognised as 'key drivers of economic growth and the right science an innovation policy is essential to strengthen and rebalance the economy for the future' (HM Treasury (2013)) and essential to addressing major global challenges facing society in terms of health, energy, food, climate and ecology, (Societal Challenges, n.d.) they are not immune to the efficiency demands all industries are facing. Pressures to be both financially efficient and carbon efficient requires expensive resources, such as large-scale high-performance computing (HPC) facilities, to be shared across communities. It is not practical or economic to duplicate large-scale scientific facilities such as the Square Kilometre Array[1] and the Large Hadron Collider,[2] or to recreate and recollect large-scale scientific data sets such as those held by the European Bioinformatics Institute,[3] so these need to be accessible and usable by geographically disparate teams. These disciplinary and geographically diverse teams need access to the same resources in order to work effectively, regardless of where they are located and regardless of which organisations (both academic and commercial) they work for. A common IT infrastructure or 'e-infrastructure' is needed to underpin this and these have emerged at both the national and the international level.

A vision of distributed computing which is at least as old as the Internet is one where the network itself is the computer – you can log onto the network with any device and have automatic access to computational resources and data storage devices anywhere on the network. This was the vision behind grid computing[4] and more recently cloud computing.[5] It is this vision which drives e-infrastructure. Broadly speaking, e-infrastructure can be broken into a number of key components: software; computation resources to run the software; storage for data which is both the input and the output of the software; the underlying network and communications to allow access to these resources; access and identity management to allow control over who has access to what; and the skills needed to use these flexible distributed 'computers'.

6.3 Network E-infrastructure

Within Europe, at the network level, GÉANT[6] connects over 50 million users at 10,000 institutions across Europe, at speeds of up to 500 Gbps. Whilst in the UK, Janet http://www.jisc.ac.uk/janet ensures researchers are linked both nationally and internationally at speeds over 100 Gbps. Janet Reach[7] allows academic/industrial partnerships access to these high-bandwidth research networks, whilst Aurora[8] allows the network research community to test and develop the next generation of network technologies and services. Even today, it is possible to layer dedicated point-to-point networks across the network infrastructure providing dedicated and secure high-speed links with high quality of service and low latencies. Looking forward, 'Software Defined Networks' (Software Defined Networking, n.d.) offer a future of 'virtual networks' where you can configure what appears and behaves as dedicated fibre cables between the distributed storage and compute resources, even though this is delivered via the existing networks. In addition, GÉANT is building upon its existing access and identity management services such as eduroam,[9] facilitating access to wireless networks in campuses around the world and eduGAIN,[10] providing interoperation between national digital identity federations to support the necessary e-infrastructure to ensure secure and trusted access to research facilities and resources (Hudson (2014)).

6.4 Computational E-infrastructure

In terms of computational e-infrastructures, these can typically be divided into HPC and high-throughput computing (HTC). HTC lends itself well to situations when a problem can be divided into smaller independent tasks, for example, if you can split a data set into small subsets and run the same algorithm on each subset; HPC is required when although you can divide a problem into tasks which can run in parallel, these tasks need to communicate between themselves. HTC can be easily provisioned using cloud computing whilst HPC requires dedicated specialised hardware. Within the UK, there are a range of HPC resource such as the Hartree Centre at Science and Technologies Facilities Council[11]; ARCHER which provides access to a 1.56 Petaflop Cray XC30 supercomputer[12]; and five regional HPC centres (e-infrastructure South Innovation Centre, N8 Research Partnership, ARCHIE West, HPC Midlands and Mid-Plus). As well as traditional HPC architectures these include new architectures such as graphic processing unit (GPU) clusters which can be applied to specialised analysis. PRACE[13] provides an European platform for sharing such national HPC provision internationally. As well as access to HPC resources, PRACE offers training programmes, code porting and optimization support, and services to enable the adoption of HPC by industry, including SMEs.

For HTC applications, EGI[14] provides a global high-throughput data analysis infrastructure, linking hundreds of independent research institutes, universities and organisations delivering computing resources and high scalability, whilst Helix-Nebula[15] allows innovative cloud service companies to work with major IT companies and public research organisations. Meanwhile, GÉANT engages with national cloud brokerages between National Research and Education Networks (NRENs) and commercial providers (such as Janet Cloud Brokerage[16]) to establish an efficient and coordinated pan-European approach to procuring cloud services by building on existing experience and supplier relationships.

6.5 Data E-infrastructure

In terms of data e-infrastructures in addition to large- and small-scale data centres, and traditional and cloud-based data storage, there are initiatives to help discover, access and share data. EUDAT[17] is a pan-European research data infrastructure addressing the full life cycle of research data: access and deposit, informal data sharing, long-term archiving, identification, discoverability and computability of both long tail and big data. OpenAIRE[18] is extending its support and guidance for researchers at the national, institutional and local level wishing to publish in OA repositories, to include support for publishing open data sets.

All these layers need to work together in order to become ‘ a collaborative data and knowledge infrastructure, leveraging on international, national, regional and institutional initiatives… an entire digital environment or network, spanning countries and scientific disciplines… an evolving framework – a digital ecosystem – to find the most efficient ways to interconnect other systems: arrays of scientific instruments, specialised data centres, digital libraries, technical software, data services, high-speed networks' (Open Infrastructures for Open Science (2012)). Even if this vision of open research e-infrastructures is achieved, it will be require a radical opening up of every step of the research process – this evolution in the modus operandi of doing research is often termed ‘Open Science' or ‘Science 2.0' (Science 2.0: Science in Transition (2014)).

Fundamentally, the motivation is to make the entire research process more transparent, easier to share and easier to reuse. The OA initiative has made the results and conclusions of research more readily accessible, whilst open data is making significant inroads in making the data which underpins that those conclusions and results. However, the results and the underlying data are just two components of the research process: the methodology itself – what you actually did to get the results – should also be open and shared. For computational research, that methodology is captured in the software or algorithms which process the data, hence the claim made by Edward Seidel, former director of the US National Science Foundation's Office of Cyberinfrastructure, that ‘software is the modern language of science these days' (Zverina (2011)). As well as repositories for data sets such as FigShare,[19] there are emerging repositories for both data and code such as Zenodo.[20] Borrowing from the concept of data journals and data citation service such as DataCite,[21] there are also emergent software journals such as the Journal of

Open Research Software[22] and SoftwareX,[23] so that both data and software can be cited by primary research outputs.

For physical research (such as chemistry or biological experiments), turning the physical lab notebook into an electronic or digital notebook enables sharing and faster reproducibility of results. Radio frequency ID tags in apparatus, chemical and samples and advanced capturing technologies via video analysis (such as object recognition and motion recognition) can automate much of the process of capturing what happened in an experiment. 3D scanning and 3D printing offers the potential of even being able to share physical apparatus in a digital form and recreate the apparatus of experiments. Research Objects[24] try to pull together all of these components (results, process, software, data, workflow, notebook, methodology) so that they all become first-class citizens of scholarly discourse and collaboration. Initiatives such as Force 11[25] are pushing the technology to provide more innovative ways of sharing scientific information.

This ability to digitally capture and recreate experiments is not without risks to scientific verification. Flawed conclusions due to flaws in the apparatus, the software or the data may not be readily detected if those reproducing the experiment or building upon the results of those experiments, were to also duplicate those flaws. Although technology may make the often arduous task of translating the experiment into natural language and subsequent researchers having to translate the description back into the apparatus and code, this may still have a place in checking the validity of the scientific method.

6.6 Virtual Research Environments

Above these technology layers, 'virtual research environments' (VREs) provide the 'user interface' by which researchers interact with this technology: providing them with the ability to access computational and data resources across the network; providing them with tools for running software, managing simulations, analysing data and visualising the results; providing them with collaborative environments for working with other researchers and sharing results, data, code and indeed 'Research Objects'. VREs alongside e-infrastructure and Open Science realise some of the original vision of Wulf's Collaboratory as a 'center without walls, in which the nation's researchers can perform their research without regard to physical location, interacting with colleagues, accessing instrumentation, sharing data and computational resources, [and] accessing information in digital libraries' (Wulf (1989)).

On one level, a VRE is a collection of tools tailored for that research community so that they can concentrate on their research rather than on understanding the complexity of the underlying technology – some may be very focused to a particular research areas such as the Virtual Physiological Human Portal,[26] whilst other such as Extreme Science and Engineering Discovery Environment (XSEDE)[27] offer a generic toolkit of shared code, applications, workflows and resources. Many VREs offer visual workflow tools, so that researchers can easily construct data analysis processes via drag and drop interfaces. However, understanding of the underlying technologies is still required to fully optimise the use of e-infrastructure. Determining if a particular problem is more suitable to HTC or HPC architectures can be difficult task manually let alone to automate. The ideal of a research being able to take their desktop environment as a virtual machine and run it unaltered on the cloud to achieve performance magnitudes higher is still some way off.

VREs also provide interfaces to other researchers and research collaborations. As well as sharing resources, data, workflows and software, VREs allow researchers to collaborate in the creation of resources, by borrowing concepts and tools (or even integrating with) social media platforms. MyExperiment,[28] for example, offers an environment similar to MySpace or Facebook for researchers to publish their workflows and in silico experiments; comment on, reuse and augment existing workflows; and to track the provenance of how a workflow has been modified by others.

Researchers are not only using social networks to collaborate during their research, they are also using social networks to perform the research – recognising that people are as an important processing engine as high powered computers with many obvious cognitive advantages. Large-scale coordination of large groups to tackle a specific problem via crowdsourcing may overcome some of the inherent weaknesses and provide much higher performances than a single individual. The Polymath Blog[29] shows this at the simplest level where mathematical problems are posted and solved by both professional and amateur mathematicians collaborating worldwide. At a more sophisticated level, Galaxy Zoo,[30] a project to mobilise the strength of citizen science to classify galaxies, has developed a generic toolkit, Zooniverse,[31] which is now used in climate science, digital humanities, biology and physics, so that crowdsourcing can become just another computational resource alongside HPC and HTC.

There are obvious risks in citizen science: it is vulnerable to malicious interference, and it is prone to feedback loops, where people can assert 'facts' purely on the basis of existing consensus which just increases the apparent consensus and reduces the inclination to challenge the consensus. The wisdom of crowds can very easily become the foolishness of crowds as demonstrated by the wealth of urban myths which propagate across social networks. It is not surprising that research into the limitations, strengths and behaviour of such social machines (Smart, Simperl & Shadbolt (2014)) is a branch of investigation and research in its own right.

6.7 Virtual communication

VREs such as the above primarily support asynchronous communication between teams and collaborations – a correspondence model where a response is not immediately expected or required. However, synchronous communications are also important, particularly as research teams grow larger and more multidisciplinary. Physical meetings can be time consuming and expensive when teams are geographically distributed. Technology provides tantalising glimpses of how such meetings could be conducted virtually. High-definition and super-high-definition video provides a more rewarding experience, almost equivalent to meeting in person, when compared to the blurred postage stamp picture from the early days of video conferencing. Improved bandwidth and low latency networks permit video and audio to be transmitted almost instantaneously.

In practice, videoconferencing is still beset by problems in terms of audio and video quality and failure to connect. Some of these problems are self-inflicted. Videoconferencing can work well when accessed from dedicated rooms with dedicated networks and well-positioned cameras and microphones. In a world where the Internet is ubiquitous and you can control both your home appliances and your large-scale computation simulations from a smartphone, many expect to be able to videoconference on the move and in busy locations from mobile devices and this can result in less than ideal video conference experiences.

The biggest challenge for large-scale collaborations is the handling of large number of participants in video conferences - unless the technology is bulletproof, the chances of at least one person having trouble increase exponentially for each additional participant. Academic videoconference support services such as V-Scene[32] in the UK, and eduCONF[33] at the international level, strive to bridge between aspiration and reality. Meanwhile is streaming ahead: motion tracking and augmented reality ‘holographic’ headsets such as Meta SpaceGlasses[34] or the very recently announced Microsoft HoloLens[35] bring the science fiction vision of a conference table attended by virtual holograms of the participants even closer to science fact.

6.8 Conclusion

Whilst we see increased collaboration enabled by technology, technology also raises barriers. One such barrier is the ability of researchers to use these technologies effectively, either because they lack knowledge or skills to adapt in an ever changing digital world, or they lack access to the specialised technical support required. Another barrier is the lack of interoperability of the various emerging and evolving technologies and e-infrastructures. We are seeing moves both within European through Horizon 2020 and globally though initiatives such as Open Science Commons[36] and the Research Data Alliance[37] to address these barriers, but there is still much to be done in terms of both technology and the capability to exploit that technology if we are bridge the gap between the visions that the technological advances tempt us with and the reality.

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