

Assessment in a Digital Age:

A research review

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The logo features a stylized, abstract representation of a star or galaxy. It consists of several overlapping, semi-transparent circles in shades of grey and white. A central point of light is visible, surrounded by a circular pattern of lines. The word "STELLAR" is written in a bold, white, sans-serif font on a black rectangular background that is positioned over the lower right portion of the graphic.

STELLAR

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This review examines the literature related to current and innovative assessment practices and systems that use technology – commonly known as 'e-assessment' or more recently technology enhanced assessment (TEA). We will use the acronym TEA or 'technology enhanced assessment' throughout, except where authors use e-assessment in quotations. The purpose of the review is twofold: to understand the potential that digital technology offers in improving assessment and to advance the debate about how it can facilitate such reforms.

Assessment is universally recognised as one of the most important – and powerful – elements of an educational experience. It is also seen as one of the hardest to reform. However, there is an increasingly demonstrated need for assessment reform, particularly if it is to keep up with other theoretical, cultural and technological developments affecting teaching and learning. Current assessment methods, especially the heavy emphasis and priority afforded to high-stakes summative assessment, are often described as outdated, ineffective and at worst damaging.

The idea that digital technologies can help transform education and specifically assessment is not a new one. New technologies and tools have long been seen to open up new possibilities due to their potentially beneficial characteristics or affordances, such as offering more personalised, instantaneous or engaging assessment experiences. In many cases this potential has been realised and demonstrated benefits. However, the literature suggests that the use of digital technologies has yet to be 'transformative' and is often used via traditional assessment methods or within pockets of innovation that are not widespread.

Thus, there remains a need to better understand how technologies can support or spur educational changes and what affordances are most useful to support the outcomes educators envisage within the current educational context. This acknowledgement of the potential digital technologies offer should also not be naïve about the complexity of the task and the myriad of influences and factors affecting successful educational change. Nor should it shy away from the significant ethical questions raised by the use of digital technologies in assessment, such as the collection, use and protection of large personal data sets, as well as how use of these tools support or unsettle inequalities within education. Thus, the question becomes how to mobilize a new vision for assessment that includes the use and development of technology, reflects an understanding of effective feedback, offers considered and equitable assessment and supports the dispositions, knowledge and literacies that are necessary to help students flourish.

To focus the investigation in this paper, three questions were devised:

1. What do digital technologies offer for educational assessment?
2. How might assessment be different when knowledge and performance can be represented digitally?
3. Where is the 'cutting edge' in such developments at present?

In its review of these questions, this paper examines the relatively short history and current scope of technology enhanced assessment; its use within formative and summative

assessment; the potential affordances and challenges it brings; and barriers and enablers to its adoption. Finally, it offers a closer look into five focus areas where digital technologies are seen to offer particular potential benefits to changing assessment in response to a changing world and learning needs. The areas of focus are:

1. The use of multiple forms of representation to enable learners to represent their learning in ways of their choice.
2. Developing new ways of assessing summative performance in different subjects
3. Developing ways to capture learning skills, competences and dispositions that are less amenable to traditional assessment methods
4. Developing ways of capturing peer interaction, group performance and collaboration
5. The role and use of learning analytics and education data mining

This review aims to provoke debate and discussion on how technology enhanced assessment can and should be used within education. In this vein and based on the literature reviewed in the paper, it also offers the following areas for further review and investigation. This review and set of recommended areas of research intends to progress the debate on the role and utility of digital technologies within assessment as a catalyst in shifting the paradigms and improving the practices of assessment to ultimately benefit student learning.

Recommendations for future research:

- Cultivate new assessment practices based on principles and theories of learning
- Develop new assessment tools that reflect pedagogical principles
- Construct new responses to the current emphasis on high-stakes summative assessment
- Respond to ethical challenges presented by the use of digital technologies in assessment
- Consider new contexts relevant to assessment using digital technologies, including learners' lives and social, cultural, educational and technical backgrounds

1. Introduction

Assessment sits at the heart of the learning process, as it provides observable evidence of learning, determines student progress and demonstrates understanding of the curriculum. More broadly, it could be said that an institution, culture, or society depicts its conceptualization of learning and ideal future citizens by how it creates and uses assessment. Recently, many scholars in the field have been warning that current assessment practices have forgotten their core purpose: to support learning. Rather, assessment is often seen to be preoccupied with qualifications and narrow achievements, and critiques of current assessment systems abound, from both scholars and dissatisfied students (Schwartz and Arena, 2009; Attwood and Radnofsky, 2007; Broadfoot, 2007; Gee and Shaffer, 2010). These critiques have propelled an imperative for reform, which is backed by a growing understanding of what constitutes effective feedback and how to track and measure learning.

A number of developments in learning sciences have contributed to a deeper understanding of the relationship between feedback processes and effective learning (Whitelock and Watt, 2008; JISC, 2010). Such developments have particularly acknowledged the importance of learner self-regulation and peer-assessment in deeper engagement and effective learning (Nicol and Macfarlane-Dick, 2006; Sadler, 2010). Another emphasis on developing and assessing characteristics and dispositions of learners that augment more traditional areas of the curriculum – often classed as '21st Century skills' – has also become a familiar mantra within the field. This focus acknowledges the digital and participatory worlds that children and young people increasingly need to negotiate (Jenkins et al, 2006). However, this view is often clouded by a naïveté about young people's natural competence and agency within these worlds, through notions like the much critiqued concept of the 'digital native' (Facer, 2012). Additionally, it is generally poorly understood how to translate these ideas into practice, and they often play out in the classroom through methods that replicate existing and traditional assessment practices rather than embracing or supporting new digital practices that give learners opportunities to flourish and have more say in their education (Claxton, 2007).

These advances have been paralleled by a dramatic increase and interest in the use of digital technologies in society and for learning. As Pellegrino and Quellmalz (2010: 130) state, 'There is an interesting and powerful confluence among theory, research, technology, and practice, especially when it comes to the integration of curriculum, instruction, and assessment'. The increasing influence of digital worlds means that young people are seen to be taking on new participatory and collaborative roles in learning online and outside the classroom, and there is a growing interest in incorporating these roles and practices inside education. Combine this with an unswerving enthusiasm from many in politics and education about the transformative potential of 'e-learning' and it's unsurprising that the use of technology for purposes of assessment – commonly known as 'e-assessment' or more recently technology enhanced assessment (TEA) – is under pressure to help facilitate assessment reform.

Bennett (2002: 14) argued that the 'incorporation of technology into assessment is inevitable'. However, as has been demonstrated by the introduction of many new 'innovative' technologies, the view that educational reform through technology is 'inevitable' and pre-determined is usually tempered by the challenges in implementation and complexity of change in education systems. Indeed, Bennett goes on to acknowledge that 'it is similarly inevitable that incorporation will not be easy' (ibid).

His hypothesis appears to be correct. Despite predictions of a technology enhanced assessment 'revolution' and a number of drivers for change in both technology-enhanced learning and shifting models of learning, educational assessment has been notably slow to adopt innovations or significant changes (Mogey, 2011; Whitelock and Watt, 2008). This reluctance to change could be due to a number of factors: the multi-layered changes that assessment requires; restrictions within the assessment system, such as the provision of reliable, systematised and large data sets under heavily scrutinised conditions; and an aversion to the risks that an assessment transformation would inevitably bring (Whitelock and Watt, 2008; Perrotta and Wright, 2010).

However, not enough research has been done to understand how technology enhanced assessment can help shape and drive wider changes in assessment. With the potential to increase personalisation, self-regulation and peer involvement in learning, as well as offering the chance to elicit and evaluate complex skills and practices, digital tools may well provide a useful catalyst for a re-assessment of the assessment system itself.

2. Purpose, scope and methodology of review

The main aim of this review is to synthesise the different strands of research and understanding related to the use of digital technologies in assessment and help determine what potential they offer for transforming the assessment system. This review intends to first investigate what current practices and understandings about 'technology enhanced assessment' (TEA) exist and what lessons can be drawn from what has already been done. This background will contribute to future research programmes that investigate new initiatives, gaps in current literature and key research questions in the area. This initial work is essential in reshaping the discourse around TEA, from that which focuses on practices that tend to replicate existing ones to supporting those that can puncture current patterns and create assessments that better reflect learning goals and realities. The work is predicated on the view that assessment needs a clearer frame of reference when considering the affordances of digital technologies for feedback and assessment purposes if it is to embody its potential to aid changes in assessment practices and norms.

Thus, the review identifies what digital technologies can offer assessment, focusing on cases where they have been used in innovative or 'cutting-edge' ways that support new processes and practices. In particular, it focuses on the following three questions:

1. What do digital technologies offer for educational assessment?
2. How might assessment be different when knowledge and performance can be represented digitally?
3. Where is the 'cutting edge' in such developments at present?

This review will consider e-assessment in educational contexts at primary, secondary, further education (FE) and higher education (HE) levels. This broad scope offers a wide overview of the innovations and various practices found in TEA, as well as hopefully providing inspiration and insight across different educational levels that may not have been previously connected. Thus, this review focuses on breadth of coverage rather than investigating areas in great depth. Mainly addressing 'formal' educational activities, the paper may draw inspirational examples from informal practices. Additionally, it identifies 'innovative' or 'cutting edge' practices as those which provide new insight or practices to the field of TEA, particularly via the opportunities they provide for transforming outdated methods. While understanding that the complex, contextual nature of innovation in education is relevant to this discussion, it is not feasible to fully explore this issue here.

While not solely focusing on technology enhanced assessment tools or computer-assisted assessment, this paper instead examines the range of potential offered by digital technologies for various assessment purposes, be they assessment for learning (formative), of learning (summative) or both. While it may refer to technology enhanced assessment tools, pilots or developments, this is for illustrative purposes only and will not offer a list of available products or make judgments related to benefits of specific tools.

A number of different areas related to the current scope of TEA, such as obstacles to its wider use, recent developments in assessment and learning sciences and different tools available for

use, will be discussed in brief. Each of these areas represents a significant body of knowledge and deserves robust treatment that is beyond the scope of this current paper.

This review has been developed in two phases. Initially, a broad literature search was conducted to identify important and relevant research in the area, both which has developed the field over time and that which is at the forefront of new discussions. While most of the literature included in this review is from peer-reviewed academic sources within the last decade, it also contains grey literature, research and government reports, and news articles determined to be current and relevant. More than 150 sources were examined to provide content or context for the review. This search led to an initial draft of the review that was discussed and critiqued at an expert seminar at the University of Bristol in May 2012 (participants are listed in the acknowledgements at the beginning of this paper). Comments and suggestions from this seminar led to further developments and additional areas of content, resulting in this final publication.

3. Current scope of 'technology enhanced assessment'

Using digital technology within assessment (known as 'e-assessment' or 'technology-enhanced assessment' throughout this paper) is not a new technological introduction to education. While the terms 'e-assessment' or technology enhanced assessment means many things to different people, they refer here to any use of digital technology for the purposes of formal educational assessment. In one form or another, technology enhanced assessment (or e-assessment) has been around for more than two decades. Throughout its lifetime, scholars have suggested that it offers traditional assessment practices potential catalysts for change and responds to growing assessment challenges (e.g., distance learning, high student populations, objective and high-quality feedback) (Whitelock and Watt, 2008).

Indeed it has been anticipated at regular intervals that e-assessment would transform and saturate the education system, as the QCA projected in its 2004 'Blueprint for E-assessment' (Mansell, 2009). Technological innovations were predicted to both change current testing practices and support greater emphasis on formative assessment instead of external examinations. However, e-assessment's 'ubiquity in UK public qualifications is still a long way off' and the importance of high-stakes testing remains formidable (Beevers et al, 2011).

Technology enhanced assessment is often simply associated with on-screen testing or automated marking and responses to student tests (often known as 'computer-assisted assessment' or CAA). Indeed, the most commonly used and technically developed form is on-screen testing, most of which uses multiple choice questions (MCQ's) and automated marking. Seen as efficient and increasingly reliable, on-screen testing has existed in professional environments for many years and has begun to appear in the education sector over the last decade (Winkley, 2010). This presence is mostly felt in the FE and HE sectors; despite the hopes outlined in the 2004 QCA blueprint, on-screen testing is still not commonly used for GCSE's or A-levels exams in the UK. Though rarer, there are also other types of on-screen assessment tools that demonstrate a wider range of learning and feedback than standardised MCQ's and involve interactive or rich media elements (Winkley, 2010). For example, adaptive assessments base the questions asked on students' previous responses (ie, correct answers lead to progressively harder questions). On-screen tests have also produced a substantial market presence and represent large commercial interests in companies like the Educational Testing Service in the US and Cambridge Assessment in the UK (Broadfoot, 2007).

Computer-based testing is only one area of technology-enhanced assessment. While these early tools remain highly visible, new practices are expanding both the use and purpose of technology enhanced assessment that include management and processing of results, learning analytics, and tools that enable instant formative feedback and collaboration on feedback processes (Beevers et al, 2011). Many of these align with the recognition that feedback and assessment should become more deeply embedded within the teaching and learning process (Whitelock and Warburton, 2011; Pellegrino and Quellmalz, 2010). Sometimes known as 'stealth assessment', assessments embedded within learning have been found to reduce test anxiety and be less disruptive to the flow of learning (Shute et al, 2010). Kleeman et al (2011) describe how embedded assessments can be used formatively as knowledge checks in a variety of multimedia forms, such as wikis, social networking sites, blogs, or web pages on computers or mobile technologies. In this way, assessment is integrated into the learning process and utilises previous research showing that use of questions for retrieval practice can be powerfully effective motivators for learners.

Similar tools can be used for measuring more complex thinking skills and learning processes, such as immersive learning environments like simulations and serious games, Web 2.0 tools, use of mobile and handheld devices, learning portfolios and electronic voting systems or learner response units (particularly found in HE) (Pellegrino & Quellmalz, 2010). Web 2.0 tools also provide opportunities for collaboration and new forms of connectivity and communication in the teaching and learning processes though the demonstration of their use is not yet wide-ranging in the literature. These tools can be seen to have contributed to some shifts in assessment that combine formative and summative purposes, such as use of portfolios to track learning, an increase in self and peer assessment and more assessment of group work and performance (Whitelock, 2010). However, among the enthusiasts, there are sceptics of the transformative potential of Web 2.0 technologies for learning, citing how social and educational identities and inequalities will not necessarily shift through use of new tools. Hughes (2009:291-292) argues that 'enthusiasm for the new technologies should be tempered with an appreciation that identity and belonging to learning communities are complex and often unresolved issues for learners'. Consequently, although social networking technologies offer new opportunities for communicating, experiential learning and for new ways of presenting content (Mason and Rennie 2008), they do not guarantee spaces which improve participation for all learners.'

Despite these new developments, studies have shown that the tools generally being used are rarely the more sophisticated ones that allow for greater flexibility, measurement of complex skills or personalisation. For example, a 2009 JISC review of advanced e-assessment techniques found 'very little evidence of some of the more advanced, Web2 technologies being used for assessment purposes' (Ripley et al, 2009:16). This review also noted that incidences of innovative practice were relatively well known amongst the e-assessment community, with few new – and little known – initiatives coming to light. The known initiatives also tended to be isolated and driven by a single person or institution, suggesting a lack of spread of innovation or new practice. As a result, Whitelock (2010:2) acknowledges that assessment has remained largely 'transmission oriented' rather than embracing the 'potential to move away from the assessment of individual skills to implement a social constructivist view of learning'.

Finally, technology enhanced assessment practices have not tended to be spread evenly across subjects or levels of education. Historically focused on subjects with 'questions with well defined answers' such as maths and science, technology enhanced assessment's breadth and scope across subjects is also now increasing (Whitelock and Watt 2008). Additionally, much of the research identified in this review focused on higher education environments and seemed to suggest that HE is currently where technology enhanced assessment uptake or innovative practice happens more regularly than in school environments.

4. Using digital technologies for different types of assessment

Research has shown that formative assessment (or assessment for learning), as distinct from summative assessment (or assessment of learning), is a powerful tool that benefits learning and student achievement (Black and Wiliam, 1998; Nicol and Macfarlane-Dick, 2006; Sadler, 1989). Nicol and Macfarlane-Dick (2006) developed further ideas about the importance of 'self-regulated learning,' which identified an important role for students in their own assessment. However, even as evidence grows on the benefits of feedback through formative assessment and more teachers employ these methods, it still remains in the shadow of high-stakes summative assessment's level of influence and unshakeable prioritisation on national and international stages.

However, summative assessment has also weathered significant criticism, in that high-stakes assessment is seen as simply retrospective recall of knowledge previously learned that measures whether all students can attain the same level rather than individual development or growth. Additionally, it is seen to offer little in the way of evaluating the actual learning process or providing transferable skills to use in the world outside school (Gee and Shaffer, 2010). This may be partly explained by the development of assessment, which has been mainly driven by ways of measuring that are valid and reliable for large-scale tests, rather than by what would be the most useful reflection of learning for the student (Whitelock, 2010).

It is also important to note that while progress has been made in theoretical understanding of assessment and feedback, a concrete and reliable comprehension of what makes feedback effective for learners – in other words, what supports them to make beneficial changes – is still under debate. There appears to be a need for more research to understand what forms and processes of feedback help reach and move learners through their education process (Whitelock, 2010). Some researching in this area have utilised existing theories of learning and assessment to develop pedagogical models of assessment that focus on self-assessment, peer assessment and reflection tasks (Luca and Oliver, 2002 and Boud and Falchikov (2007), cited in Whitelock, 2010).

Both formative and summative assessment are deeply embedded within current educational systems. Recognising that both types serve distinct educational purposes, it is also important to note they are not necessarily exclusive processes and are often intertwined in teaching and learning activities. Technology enhanced assessment may offer some alternatives to suggestions that these types of assessment may be coordinated to provide more useful feedback (e.g., using summative assessment for formative purposes) (Black and Wiliam, 2009). Technology enhanced assessment has been used for both summative and formative assessment activities, though it is particularly suitable for formative assessment purposes, as it provides mechanisms for sharing immediate feedback, diagnosing and testing skills and knowledge, peer- and self-assessment, as well as offering private and non-judgmental feedback.

A closer look at the use of digital technology for summative assessment purposes can be found in section 7.2, but some examples where it has been used for formative assessment purposes are listed here:

- Virtual environment Quest Atlantis (www.atlantisremixed.org) uses a game-based curriculum that supports students to develop inquiry in ecological sciences. A study of two classes using Quest Atlantis found that the classes using QA had larger gains in

understanding and achievement than those that did not, and students that engaged more with the environment's formative feedback showed even greater gains (Hickey et al, 2009).

- The AsTTLE project in New Zealand (<http://e-asttle.tki.org.nz/>) is a software application that enables educators in schools across the country to create tests by selecting items from an online system. Teachers have access to large, calibrated banks of test items and can select those which reflect the test purpose and their own teaching. While AsTTle was developed in higher education, it is used by school teachers and administrators. Performance data is entered into the system, allowing teachers and administrators can access valid, reliable information of student performance, as well as relevant teaching resources. While meeting national standardised requirements, the system also provides feedback for teachers and ultimately supports assessment for learning, rather than just assessment of learning (Ripley et al, 2009; Hattie and Brown, 2007-2008).
- The REAP (Re-engineering Assessment Practices) project aimed to redesign feedback and assessment practices across HE institutions based on a conceptualisation of assessment via a self-regulation model, which asserts that learning is deeper and more meaningful when students actively share responsibility for their learning and assessment. The REAP project redesigned 19 classes at three Scottish institutions between 2005-2007. Each institution worked to a set of articulated principles that conceptualised their understanding of assessment and feedback, which were then transformed into new practices that involved regular opportunities for peer- and self-evaluation. Different technologies were involved in the redesign and new assessment practices, including podcasts, blogs, electronic voting systems, online tests, e-portfolios, discussion boards, simulations, intelligent homework systems and feedback software. The project demonstrated a number of successes identifying 'improved learning achievements, high levels of student satisfaction, (...) and, in some cases, reduced teacher workload' (Nicol and Draper, 2009: 194).

It is important to consider both types of assessment in the discussion on digital technology's potential to support changes in assessment innovation and reform, particularly in how the risks and complexities of change differ for each (Winkley, 2010). Digital technologies may appear to offer more potential to formative assessment because innovation within this purpose attracts less scrutiny and seems less risky. The use of digital technologies for summative assessment purposes is less straightforward, as changes to more standardised assessments face a number of constraints. However, recent projects and initiatives attempting to merge formative assessment within multi-level summative assessment processes are emerging (See section 7.2).

5. What do digital technologies offer assessment? The good and the bad

The possible benefits that digital technologies offer to learning and specifically to assessment are well documented. Becoming equally apparent are the challenges and threats that they may also bring. This is particularly the case with their use in assessment, which relies upon the collection and analysis of data, plays a critical role in determining learners' futures and raises a number of ethical issues. This section briefly outlines both the possible benefits and dangers associated with the use of digital technologies, though some of these areas will be investigated again in more detail in subsequent sections of the paper.

A list of possible affordances or benefits that technology may offer assessment is outlined below, as amalgamated from a number of sources (JISC, 2010; Pellegrino & Quellmalz, 2010; Winkley, 2010; Schwartz and Arena, 2009; Angus and Watson, 2009; Whitelock and Watt, 2008; Whitelock et al, 2006). Assessment with the use of digital technologies has been seen to:

- **Provide immediate feedback** – Can offer 'real-time', learner-led feedback that diagnoses and reduces misconceptions quickly (e.g., multiple choice questions in a lecture) and provides more opportunities to act on feedback from a range of audiences (teacher, peers, or large community via blog or web site). This can also lead to useful and new forms of teacher and learner dialogue, improvements of the assessment experience and increased student engagement.
- **Potentially increase learners' autonomy, agency and self regulation** – Could support more personalised responses to work and progress and can facilitate self-evaluative and self-regulated learning through diverse collections of evidence, immediate formative feedback, better tracking of progress to learning outcomes and reflection on achievements. The visualisation of data is particularly relevant here.
- **Support for collaborative learning** – Offers opportunities for peer assessment, undertaking and tracking knowledge building and sharing activities, co-evaluation and social interaction.
- **Provide authenticity** – Could present challenging problems and ways to assess complex skills like problem-solving, decision making, and testing hypotheses, which is argued to be more authentic to future work experiences and what skills and knowledge will be required after formal education.
- **Widen range of measurement** – Via the ability to create and visualise complex data sets and models that consider multiple factors, digital technologies can elicit and measure multi-faceted skills, sets of knowledge and cognitive processes that have previously been difficult to assess. For example, simulations can simultaneously measure technical computer skills, decision-making and strategy processes as well as subject specific skills like scientific enquiry. These also include tracking cognitive processes that can be developed into patterns showing levels of expertise.
- **Flexible and appropriate responses** – May offer choice in approach, format and timing of assessment for students, who can access assessment at a time and place of their own choosing, with no constraints due to time or location. Additionally, digital tools like simulations provide multiple modalities and could offer more accessible assessment than text-based tests for students with varied learning styles or language backgrounds.

Regular feedback can also make students feel less anonymous and more personally connected to their learning and courses, particularly in HE settings. These possibilities can also challenge traditional methods of assessment and require a rethink of old practices.

- **Increase efficiency and reduce teachers' workloads** – Potentially improves efficiency of data management such as marking, moderating and storing information by helping teachers use their time and resources better; offers more environmentally friendly administration of assessment.
- **Improve student performance** - Evaluations show that e-feedback can improve student performance and demonstrates other benefits, such as better student engagement (see Whitelock and Watt, 2008; Angus and Watson, 2009).
- **Integrate formative and summative assessments** – Summative assessments tend to be retrospective, in that they test knowledge previously acquired without leaving an opportunity for ongoing learning. Digital technologies can integrate assessment and instruction, as in immersive learning environments or programmes that monitor how students solve problems on the computer and provide immediate feedback.
- **Improve assessment validity and reliability** – Can help track assessment validity (if the activity is a fair measure of skill and understanding) through use of rich media rather than just text. Also provides improvements in reliability of scoring and robust data sets for deeper analysis.

Of course these affordances do not guarantee benefits, and a look at the possibilities technologies offer to assessment must also consider some of the more concerning issues and outcomes. Many of the possibilities offered by technology are tempered by the practical or educational difficulties of implementing them to a high level of effectiveness. For example, successful use of computer-assisted assessment for multiple choice testing involves significant institutional commitment, technical infrastructure, and high levels of quality assurance practices (JISC, 2010).

Likewise, taking a set of tools and affordances at face value can be deceiving. Many in the field have argued for a more ecological approach to examining the potential of digital technologies as innovations in education. Rather than taking a technologically determined perspective that views a tool as a 'black box' with a set input and output, educational innovations using technologies should acknowledge how the unique cultural, social and institutional context helps determine its use and outcomes. (Jenkins et al, 2006; Zhao and Frank, 2003). As Jenkins et al (2006: 10) point out: 'It matters what tools are available to a culture, but it matters more what that culture chooses to do with those tools'. However, as Whitelock et al (2006) points out, early development of ideas and tools based on pedagogical issues can also soon be overshadowed by tool development.

Draper (2009b:309, 307) discusses the still-developing understanding of what makes effective feedback and investigates what constitutes working feedback loops – that is, feedback that causes learners to 'do something differently'. He demonstrates the likelihood of differences in motivations and understanding of feedback between teachers and students and warns that e-assessment 'is even more vulnerable to such questionable assumptions' as it automates what can be a highly emotive, nuanced and sensitive dialogue. With a better grasp of how feedback can match learners' motivations and expectations, assessment practices could open new dialogues and truly support learners to do things differently.

There has also been an increasing awareness of challenges and threats presented by the growing use of digitised information and data for education and assessment, despite common assumptions that collecting and measuring data is a good thing and automatically leads to objectively determined and deeper understandings. However, Goldstein (2012) questions whether this 'data deluge' is necessarily a wholly positive development and demonstrates how educational data analysis (such as that related to league tables and exam results) can be questionable and misleading.

Additionally, the growing prevalence and sheer volume of the digitalisation of data raises ethical concerns around how the data is collected, used and stored. (While this area is discussed in greater detail in section 7.5, it is briefly addressed here.) Data management, ownership and sharing will only grow in prevalence for both individuals and the organisations and networks they belong to (Facer, 2012). Indeed, data flow within the education sector, at classroom, institution and national levels is prolific, which raises ethical issues about how and if learners consent to, can access, own or control their own personal data. Facer (2011) describes how this proliferation of data, significant increase in use of surveillance technology and constantly expanding 'digital footprints' for auditing and management of educational performance, as well as the slow integration of technology that shares control with students (e.g., portfolios, social software), reflects how schools' responses to current socio-technical changes have the potential to create school atmospheres based on control rather than democracy and young people's agency.

This discussion should also consider the types of data that are collected and deemed relevant and useful to support learning and educational decision making. As discussed in section 7.3, there is an increasing call to include more affective skills, attributes, and dispositions within education, which raises questions not only of how to assess these but if such personal characteristics should be evaluated at all and, if so, how that information is protected.

6. Barriers and enablers in technology enhanced assessment adoption

A significant body of literature outlines the challenges related to educational reform and innovation, and a similarly robust set of research has outlined why successfully harnessing or exploiting the potential of technology can be difficult. Innovation in assessment is a delicate matter whether technology is involved or not, and it is seen to be particularly risky in the area of summative assessment, which is publicly accountable, heavily controlled and has important consequences on the cohort of students undergoing assessment. The obstacles specific to the wider adoption or spread of technology enhanced assessment in particular have been documented by many scholars, and are briefly mentioned here (amalgamated from Moge, 2011; Mansell, 2009; Whitelock and Watt, 2008; Ripley, 2007; Whitelock et al, 2006; Whitelock and Brasher, 2006):

- Potential barriers to the adoption of technology enhanced assessment practices:
- Practitioner concerns about plagiarism detection and invigilation issues
- Difficulties in scalability and transferability of practices, particularly in HE when different departments often have autonomous, separate working practices and cultures
- Concerns over reliability and validity of high-stakes assessment (such as how to ensure all students receive equivalent tests if questions are selected at random from a question bank)
- User identity verification and security issues
- Lack of staff time and training for rethinking assessment strategies and how to use new technologies, from a technological and pedagogical perspective
- Cost of investment - Implementing new technology systems requires significant investment in training, support and interoperability. Additionally, some tools require large capital investment and infrastructure that many institutions do not want to prioritise (e.g. having enough computers for those taking exams for on-screen testing)
- Exam boards are highly concerned with ensuring standards are not affected
- Lack of policy leadership and system-wide imperatives
- Constraints within the exam system, particularly in secondary and FE sectors
- Lack of suitable physical spaces for technology enhanced assessment, which have not developed for the needs and purposes of technology enhanced assessment

Despite the large number of challenges facing those promoting technology enhanced assessment, other studies have identified characteristics of projects and implementation that have enabled successful implementation and engagement. Beevers et al (2011: 3) found that projects with solid planning, 'minimal fuss', a clearly established pedagogic need and 'authority for change' became well established. Whitelock and Brasher (2006) note the following enablers: active leadership and management support, pedagogical and technical support for staff and solid staff development. Individuals who champion tools and practices have also been seen as important to the success of many projects, especially regarding summative assessment (JISC, 2010). Finally, the REAP project (www.reap.ac.uk) suggests multiple strategies are important when improving assessment practice, including conceptual frameworks for assessment, supportive institutional policies and departmental initiatives,

student engagement in the process and quality assurance procedures to evaluate the entire process.

Many educational innovations using technology have thrilled with potential and disappointed in reality. This and the deep entrenchment of the current assessment system may encourage a gloomy outlook when considering the potential for digital technologies to help reform current assessment processes. However, such a track record should not discourage a deeper look at the possibilities such tools offer for assessment.

7. Looking more closely at technology enhanced assessment practices: exploring five areas

The following sections of the review focus on recent innovations and the 'cutting edge' of assessment with digital technologies in certain focal areas, specifically where tools have supported changes in practice. This list comprises a set of areas in which digital technology could make significant changes to assessment. Other areas have also come to light that deserve further treatment in future research but are not included here, such as applying digital technologies to support self-regulation, supporting greater efficiency in existing assessment approaches and development of radical new policy initiatives for national assessment systems. It is also important to note that some projects or uses of digital technologies for assessment discussed here will encompass more than one of these thematic areas but may only be mentioned in one.

The five focus areas are:

- The use of multiple forms of representation to enable learners to represent their learning in ways of their choice
- Developing new ways of assessing summative performance in different subjects
- Developing ways to capture learning skills, competences and dispositions that are less amenable to traditional assessment methods
- Developing ways of capturing peer interaction, group performance and collaboration
- The role and use of learning analytics and education data mining

7.1 Use of multiple forms of representation to enable learners to represent their learning in ways of their choice

There is considerable potential for multimedia technologies to make feedback richer and more personal and for a wider range of learner skills and attributes to be demonstrated through assignments involving, for example, e-portfolios, blogs and wikis. In addition, online tools can support peer and self-assessment in any location and at times to suit learners – the value of peer and self-assessment in developing learners' ability to regulate their own learning is increasingly recognised (JISC, 2010: 11)

Among its many offers for assessment, digital technologies present opportunities for learners to demonstrate their competencies and knowledge in different formats, through various media and according to their own personal preferences. Being able to capture, review and author multiple forms of representation of knowledge and skills can allow learners to have more personalised evaluation, more opportunities for peer- and self-assessment, and greater flexibility and choice on how they learn. Whitelock (2010) suggests that the digital nature of evidence will only increase in time and is likely to become distributed across various media, which will support authentic experiences and put the process more in control of the learners.

These affordances match the recognition of emerging digital cultures that can encourage greater levels of authorship, autonomy, collaboration and choice for students in the process of learning, which often happens outside school. Jenkins et al (2006) acknowledges the growing

number of children and young people who are becoming 'media creators' or digital technology users who blog, upload or remix media content and who are involved in 'participatory media cultures' that support sharing one's creations and increase possibilities for civic engagement. They argue that these cultures offer benefits important to succeeding in the world and therefore a young person's access to these cultures impacts on their future outcomes. Additionally, Schwartz and Arena (2009) discuss how choice is one of the most important concerns for parents, educators, children, future employers and a democratic society and therefore the capability to make choices and manage the ensuing responsibilities of those choices should be at the centre of assessments.

Certain forms of technology-enhanced assessment offer the possibility for learners to become central actors in evaluating their own learning, through methods and models of representation of their choice. This also aligns with research showing that effective learning does not happen through 'passive receipt of teacher-delivered feedback' but when 'students actively decode feedback information, internalise it and use it to make judgments of their own work' (Whitelock and Watt, 2008: 152). Tools used to support assessment in this area include Web 2.0 tools which promote authorship, production, and creativity or mixing of media, such as wikis, blogs, social networking activities, social bookmarking, podcasting, e-portfolios, RSS feeds, and forums. Many of these are often encapsulated on a class or school virtual learning environment though they also reach further afield. Higher education institutions are more likely to demonstrate learning using production or authoring tools (often blogs or wikis) though how to undertake assessment of such content is itself an area of debate (Gray et al, 2010).

Lessons can also be learned in this area from practices in more informal learning settings, such as the development of online 'badges'. Badges comprise an alternative accreditation system that often uses communities to validate skills and knowledge of its members who are then awarded virtual badges (or online visual icons) that recognise different skills or achievements. Often found in gaming environments, badges are gaining support among educators and academics that see them as a new way to acknowledge and represent students' talents, achievements and skills, including that which happens out-of-school. Badges offer an alternative assessment method of representing an individual's range of learning and are portable and useful during and after formal school years. They can also be used to scaffold learning trajectories so learners can visualise and understand possible pathways and the qualifications they need to achieve along each one. While badges have been enthusiastically received by many working in the field of digital media and learning, an understanding of using badges as a viable alternative form of assessment is in its early phases and has not yet deeply looked at a number of problematic issues including learner motivation, young people's perspectives on the use of badges, how accreditation systems promote equality or replicate existing hierarchies and the implications of evaluating every activity that young people access, particularly related to informal learning.

Despite the importance of recognising these cultural practices and the relevance of democratic participation, educational institutions often struggle to incorporate such cultures. Schools are not necessarily equipped or prepared to manage the requirements and ethical issues related to digital cultural practices. For example, use of social software or social networking tools require students to participate in communities that depend on complex social identity issues that some learners may not be comfortable with, and thus these practices may become divisive (Hughes, 2009). Similarly, Jenkins et al (2006) acknowledges a 'participation gap,' within which not all children or young people participate online in equal ways or gain benefits from such networking or participation, in and out of school.

A selection of related case studies is next presented in this section, with e-portfolios given additional attention because of the recent amount of educational interest in them.

Case studies:

- **Use of mobile devices in schools** – The Learning2Go project (www.learning2go.org) in Wolverhampton uses handheld devices with primary and secondary age students and allows students to create and use a variety of media they collect on mobile devices. Evaluations of the project have found increases in students' self-assessment, interest and engagement with different curricular subjects and a likely positive impact on more conventional tests (Ripley, 2007).
- **Use of mobile devices in workplace settings** – The ALPS (Assessment and Learning in Practice Settings) project develops assessment in workplace settings for Health and Social Care students at HE level. An area of focus is the use of mobile technologies for connecting students in workplace settings to learning material and flexible assessments. This extends the opportunities for assessments that students have and allows them to use a variety of media generated from authentic experiences as part of their learning and assessment material. (<http://www.alps-cetl.ac.uk/index.html>)
- **Mozilla Open Badges** – Mozilla has developed the idea of 'badges' through a Badge System Framework, which envisions badges as image files that hold metadata outlining the skills or achievements of the badgeholder, as well the issuing body. Badges can also link back to the evidence supporting the award and could be portable and displayed on various social networking or recruitment sites. The framework suggests that badges could be awarded via various mechanisms: through formal awarding bodies, from multiple assessors (as in 'gurus' in a particular online community) or self-awarded. Mozilla is developing an Open Badges Infrastructure that will allow the creation and hosting of badges, including a 'badge backpack' that individuals can use for storing and moving their badges. (<https://wiki.mozilla.org/Badges>)

E-portfolios

Significant interest and research has centred on the potential of Web-based portfolios or 'e-portfolios' for learning. The term 'e-portfolio' can mean different things in different contexts but generally refers to a personal online space that acts as an assessment framework and supports a variety of functions, including information repository, organisation of learning, and collaboration. In portfolios, students generally upload artefacts and then consider how these reflect certain skills or competences. Both a learning outcome in Becta's 2005 Harnessing Technology strategy and a focus within the QCA's 'Blueprint for E-assessment', e-portfolios have enjoyed popularity and scrutiny from a number of government and research bodies (Ripley, 2007).

A Becta report highlighted the benefits e-portfolios offer, including support for reflective thinking, development of creativity, accommodation of students with a range of ability, increased collaborative processes and improved scaffolding via software structure and tools (Becta, 2007). They can also help personalise learning for students within or between different educational institutions. However it also noted that use of e-portfolios 'benefit learning most effectively when considered as part of a joined-up teaching and learning approach, rather than as a discrete entity' (ibid:4). Garrett (2011) also notes that the original pedagogical intention of e-portfolios to support learning and reflection has shifted and portfolio software now often focuses on providing assessment data rather than pedagogical improvements as its main outcome. He argues for a new portfolio design paradigm that

returns to the original pedagogical purposes of the tool and incorporates more collaborative, shared elements reminiscent of social software that students are using outside schools. Stone (2012:6) takes this point further by stating that the perceived benefits of e-portfolios in the media tend to relate to efficiency and cost, and therefore 'systems have sold themselves primarily on the basis of reduced cost and decreased completion time'. However, he warns that efficiency should never be the primary reason such tools are used in schools.

Stretching the use of e-portfolios from individual showcase pieces to include peer-involvement and collaboration has also demonstrated advantages. Van Aalst and Chan (2007) examined how student-directed e-portfolios can support learners to assess collaborative knowledge building and found that the portfolios helped develop deeper understanding of the knowledge-building process and provided demonstrable evidence of both individual and group knowledge building. Garrett (2011) tested a portfolio design model that emphasises personal ownership, social learning, and ease of use and found that these three characteristics (in particular, social learning) were strongly favoured by students and should be incorporated into portfolio design. Similarly, Barbera (2009) describes how use of a 'netfolio' or a network of individual portfolios incorporated peer assessment and 'co-evaluation' that demonstrated high levels of teacher and student satisfaction with the assessment process, improvement in learning results and more self-reflection from learners on their own work due to the involvement of peers.

E-portfolios are commonly used for assessment and compilation of vocational qualifications materials, specifically acting as standards repositories, collections of evidence and a means by which to cross-reference evidence to standards. They have been seen as a significant improvement over previous paper-based portfolios, both for practical (more time efficient) and pedagogical (increased reflection and quicker feedback) reasons (Stone, 2012). In this way, e-portfolios can also offer alternate forms of assessment for students who struggle or disengage from more traditional methods of assessment. For example, a chef's course in West Suffolk College used e-portfolios to demonstrate student performance without a need for written assignments, which were problematic for many of the learners. Photos for evidence were 'bluetoothed' to tutors for comments and then shared with peers and used again when relevant for lectures (Whitelock et al, 2006).

The E-Scape (E-Solutions for Creative Assessment in Portfolio Environments) project led by a team at Goldsmiths University is a well known example of innovative assessment using e-portfolios. E-Scape focuses on assessing learners' creativity, innovation ability and teamwork in design and technology (Kimball, 2007). Through the project, students go through the design process using PDA's and E-Scape records the evidence of their progress. Assessment of e-portfolios draws on Thurstone's Law of Comparative Judgment, trading the conventional criteria-based evaluation for more norm-based referencing, in which two pieces of work are compared against each other to determine which one is better, from a holistic perspective. This task of comparison is completed multiple times by various markers to generate a rank order of submissions, and the overall process was found to be remarkably reliable.

7.2 New ways of assessing summative performance in different subjects

Summative assessment is generally characterized by standardised testing that aims to elicit, demonstrate and analyse what knowledge and skills learners have accumulated after a course of study. High-stakes summative assessment is highly controlled and regulated, as well as massively influential on the educational outcomes of a student. One bad test score can have a huge impact on a learner's educational opportunities and chances.

While there have been a number of advances in formative assessment related to technology, there are markedly fewer for summative assessment, for reasons noted earlier in this paper. Standardised, multiple choice question formats maintain dominance in the testing world, resulting in 'an overreliance on simple, highly structured problems that tap fact retrieval and the use of algorithmic solution procedures' (Pellegrino and Quellmalz, 2010: 122).

However, in some places large-scale testing is beginning to take advantage of technology's ability to elicit, capture and demonstrate complex sets of data. Initiatives and projects in different countries have begun to shift summative assessment practices and demonstrate how the different types of assessment can be merged so as to support more effective and ongoing learning. These developments are happening at different volumes across school subjects, though science seems to be the one leading the way in 'exploring the presentation and interpretation of complex, multifaceted problem types and assessment approaches' (Pellegrino and Quellmalz, 2010: 121).

Innovative initiatives have sprung up in a few countries over the past decade. The UK's KS3 ICT Test Project was a large and well known technology enhanced assessment project that aimed to develop a virtual world similar to Second Life, in which learners solved challenging 'real-life' problems. This world would incorporate assessments that evaluated students' knowledge and cognitive skills to provide various data sets – from individual student information to national data on student competency levels. The project was lauded internationally (see Honey et al, 2005) but in practice teachers remained unconvinced of its benefits and the tests were not as innovative as imagined, often appearing similar to more conventional testing activities (Ripley, 2007).

Perhaps because of the looser constraints on exams and high-stakes testing in higher education as compared to schools, HE practices also offer a number of innovative ways of evaluating students' progress. For example, Cathy Davidson, a professor at Duke University and scholar on new media and technology, recently assessed one of her university courses (entitled 'This Is Your Brain on the Internet') through an experiment in 'crowdsourced grading'. The assessment was based on a point system determined by peer review and teacher commentary, and students earned points via crowdsourcing by peers who offered weekly evaluations of their peers' written blogs. The experiment was an effort to try to incorporate the participatory learning happening online and outside of the classroom with assessment inside it (Hendry, 2009). Davidson found that student effort and quality of work overall increased compared to previous classes.

As previously discussed, summative assessment need not be seen as distinct or separate from more formative evaluations. Pellegrino and Quellmalz (2010) have identified ways that classroom assessments can support both formative and summative assessments and outline a number of different initiatives that depict how formative feedback can be intermingled with summative performance. Some from their research and that of others are described here:

- **The DIAGNOSER project** maps student knowledge through guided enquiry in physics. The project assesses students' understanding of physics and supports them to identify their misconceptions through immediate and cumulative feedback. Teachers receive the assessment results and can choose how to continue instruction based on the students' performance and identified misconceptions. A US study validating this project showed that students who have used it did better on the state science test than other students who had not used the programme.
- **SimScientists**: A US project called SimScientist (<http://simscientists.org>) use simulation-based science assessments as summative assessments that include complex

models of science concepts and offer difficult enquiry activities. This project also examines how simulations can be used for formative assessment within the curriculum and instruction, as they give individualised feedback on students' metacognitive and self-evaluation competences.

- **ASSISTment system:** This project features an online testing programme which acts as a 'pseudo-tutor' and provides feedback for students working on middle school level mathematics. The system gives students specific, tailored feedback based on responses to questions through hints, messages and scaffolding questions. Summative and formative data is also shared with teachers, in terms of how students complete the overall test and specific feedback on particular areas. Evaluation of the programme suggests positive benefits, including student perceptions that the programme helps them with the test and predicted test scores that are better than the average (Whitelock et al 2006).
- **TRIADS system:** The TRIADS system was developed by the University of Derby and is a flexible and easy-to-use assessment system that includes various question styles in different formats to help evaluate 'higher-order learning skills.' The system has been used for formative and summative assessment purposes at both the University of Derby and others around the UK (at Derby, it is used to deliver more than 10,000 medium- to high-stakes summative assessments each year). (Whitelock, et al 2006:26).
- **Audience response systems:** Hancock (2010) describes the use of audience response systems (ARS), most commonly used for formative purposes, for summative assessment. He identifies an apt place to use such tools are large university courses that often contain important foundational knowledge but can leave students feeling anonymous and 'lost in the crowd'. ARS have been used successfully to provide formative assessment within such large lectures, but Hancock reports on their use to replace standard paper-based summative tests. Such use provided greater efficiency and security for teachers though did not essentially change the nature of the basic multiple choice question tests. Additionally, students experiencing the use of ARS for formative and summative assessment responded favourably to its use for formative feedback but were significantly more sceptical about the use and fairness for summative purposes.

7.3 Developing ways to capture learning that is less amenable to traditional assessment methods

'When confronted by problems, especially new issues for which solutions must be created out of whole cloth, the ability to think creatively, critically, collaboratively, and then communicate effectively is essential. Learning and succeeding in a complex and dynamic world is not easily measured by multiple-choice responses on a simple knowledge test. Instead, solutions begin with re-thinking assessment, identifying new skills and state standards relevant for the 21st century, and then figuring out how we can best assess students' acquisition of the new competencies— which may in fact involve others doing this assessment (e.g., community peers)' (Shute et al, 2010: 4).

Contemporary educational discourse increasingly emphasises the inclusion of skills and attributes beyond the traditional curriculum. Current education literature is rife with the notion of '21st century learning', considered to comprise those attributes, skills and areas of knowledge that are 'critical for every child's success as a worker and citizen in the 21st century' (Honey et al, 2005: 4). Countries and organisations across the world outline similar

versions of these competencies that are seen to be essential for success in modern and future society¹. Consequently, the imperative to develop education systems that prepare students for the future spreads enthusiastically across national and international discourse in political, business and educational sectors (Claxton, 2009).

This discourse aligns with that of the 'knowledge economy' that places national and global economic success in the lap of investing in education and the increase of 'skills', a narrative that has been disputed as the only option (e.g., Facer, 2012 and www.beyondcurrenthorizons.org.uk). What exactly constitutes '21st century skills' depends on who you ask but core dimensions tend to include generic skills like problem-solving, complex decision-making, creativity, innovation, collaboration, global awareness, digital literacy, communication and the ability to be self-motivated. These '21st century skills' often appear to align with the 'higher-order' thinking skills identified in Bloom's Taxonomy of Educational Objectives, which describes a hierarchy of increasing cognitive skills, depth of understanding and engagement with learning.

It is important to note that these frameworks and notions of 21st century learning have been criticised and questioned as to whether they offer the most suitable sets of qualities on which to focus. Exploring alternative frameworks is very pertinent to the discussion as it ultimately asks what it is that's worth learning and assessing. Claxton (2009:178) points out that the rhetoric of 'lifelong' learning, skills-based approaches and experiences that provide resilience to future changes often falls flat when it comes to how such initiatives are practically put into action due to their vague, haphazard or 'scientifically dubious' nature. Scholars such as Claxton (2009) and Buckingham Shum and Deakin Crick (2012) suggest that considering learners' orientations towards learning – or their 'dispositions' – rather than 'skills' may lead to more fruitful outcomes, as this recognises that different people are differently 'disposed' to using their skills or knowledge at certain times and in certain contexts. In order to best support learners then, educators should help them 'disembed any ability from its context of acquisition' so they can transfer the use of skills and knowledge from one situation to another (Claxton, 2009:184).

Jenkins et al (2006: 6) also identify a set of new skills and literacies that students need, almost all of which 'involve social skills developed through collaboration and networking'. Chief among them is 'media literacy', which is broken down into more specific elements of play, performance, simulation, appropriation, multitasking, distributed cognition, collective intelligence, judgment, transmedia navigation, networking, and negotiation. Shephard (2009) states that higher education is also increasingly interested in measuring 'affective outcomes', including values, behaviours and dispositions that in particular may be seen to relate to certain careers (e.g., evaluating how 'caring' future doctors are) but also importantly notes that many teachers remain cautious about teaching and assessing affective domains, raising the issue about what characteristics are possible, ethical, and indeed desirable to evaluate.

However, the challenge particularly relevant to this paper is what kind of assessment drives the teaching that supports the competences and dispositions that we think matter. Inherent to the discussion of how to embed skills, knowledge, dispositions and literacies into education is how they should be assessed. A 2005 survey of educational assessments that support '21st century learning' notes that the 'movement to embrace and foster widespread adoption of 21st century skills hinges on identifying ways to assess students' acquisition and application of this

¹ Though versions are found in many countries and international organisations, notable examples can be seen in the US Partnership for 21st Century Skills (www.p21.org), the UK curriculum's Personal, Learning, and Thinking Skills, as well as the EU's Key Competences for Lifelong Learning (http://ec.europa.eu/dgs/education_culture/publ/pdf/ll-learning/keycomp_en.pdf).

knowledge' and 'there is a comparative lack of assessments and analyses focused on elements of 21st century learning' (Honey et al, 2005: 4-5). Thus, there is a recognised need to further develop new assessment tools that measure higher-order, more complex thinking – such as the application of knowledge to complex situations (Honey et al, 2005; Shute et al, 2010).

The assessment of such skills or dispositions has been shown to be more complex than many current assessment practices are capable of, as they are identified as difficult to calibrate, measure and evaluate. This may be in part because they can be seen as too generic or vague to know how to cultivate or assess in any meaningful way. Bennett and Barker (2012) make a similar argument into the complexity of measuring the higher-order thinking skills in Bloom's taxonomy. Current assessment systems therefore are often measuring what is easy to assess rather than what has been learned. So what do digital technologies offer in helping measure the difficult things?

Valerie Shute and colleagues (2010) have researched how to develop psychometric models that can evaluate certain competencies and use immersive learning environments to elicit and measure data related to these. Recognising that current 'immersive games lack an assessment infrastructure to maximise learning potential,' Shute and colleagues first conducted a significant literature review to identify relevant competencies to assess. They chose to develop competency models for systems thinking, creativity, collaborative learning, and managing social identities and reduced each one to a granularity that could be measured in order to diagnose different levels of competency. Using a process called 'evidence-centered design' (ECD) to support the validity of the assessments they devised, the researchers designed immersive learning environments by listing the knowledge, skills and attributes that should be assessed, identifying behaviours that demonstrate these elements and crafting tasks that should elicit these behaviours and create the assessment evidence. They then measured the competencies within immersive learning environments that provide 'stealth' assessment to support students' learning 'via formative feedback, collaboration and personalised content.' (ibid: 3-4).

Other simulations and serious games have been used for similar educational purposes, though the technology used in simulations can vary widely and be expensive to develop. Similarly to the work of Shute described above and adaptive assessment discussed earlier, assessment in many simulations is embedded as an element within it, which does not distract players from playing and encourages multiple plays. Simulations can assess both foundational knowledge (e.g., functions of organisms in ecosystems) and interaction of dynamic elements (e.g., how those organisms interact in the face of changing variables) (Pellegrino and Quellmalz, 2010).

Similarly, Gee and Shaffer (2010) offer reasons for increasing the use of good video games in education (e.g., support problem solving, track vast amounts of knowledge across time and offer engaging, sequential challenges) and go on to assert that the focus on developing games for learning should focus on designing games for testing. They also suggest that assessment design can learn lessons from game design, in that games are first built around challenging and testing players and 'the learning design then follows from the assessment', an opposite method to the ways most educators design assessment (ibid: 10). However, as Winkley (2010: 11-12) notes, such assessment 'can also become "too implicit" so that learners don't necessarily think carefully about the detail of the outcome they've achieved, so serious games can often have support resources to assist in making the experience more "formative" '. Additionally, the difficulty of using assessment via educational games is noted elsewhere as many game-based assessment systems are 'bespoke to the game' and the learning is often hard to transfer (Ulcsak, 2010: 35).

Beyond games and simulations, other types of tools have also been used to elicit and capture higher-order thinking skills. Bennett and Barker (2012) investigate how the use of electronic voting systems (EVS) for peer assessment purposes helps develop higher-order skills and impacted motivation and engagement of learners in the process of assessment. As a result of the use of EVS tools alongside peer assessment, this study found that student marks, as well as overall quality of work, increased, as did levels of student interaction with each other and within lecturers. This was seen to be in part due to deeper engagement with the subject and improved higher-order skills. Draper (2009a:285) also identifies the potential for engaging students with multiple choice questions (MCQs) through the use of EVS. Acknowledging that MCQs are often associated with 'the lowest kind of learning of disconnected facts', he proposes new ways of using them that support deeper learning through developing links between questions, supporting students to write MCQs and greater peer interaction.

7.4 Developing ways to capture peer interaction, group performance and collaboration

There is a burgeoning body of research that increasingly emphasises the importance of peer collaboration and networks for learning, and Van Aalst and Chan (2007:175) refer to 'paradigmatic shifts' in learning theories recognising that learning is 'social, distributed and collective'. Such emphases in contemporary discourse on learning have led to exploration of concepts like collaborative knowledge construction, situated learning, distributed learning and communities of practice. This increasing acceptance of learning as relational, situated within a particular social context and mediated through social interactions is strongly rooted in the socio-constructivist perspective of Vygotsky (1978).

Thus, learning is not seen as a passive or solo venture but rather as one that is active, social, contextual and situated in real-world living. Dawson (2010) cites studies that have connected students' networks to improved learning performance, development of a sense of community and information and resource exchange. Social learning through methods like small group work has also demonstrated positive impacts on performance and shifts the focus from that of content to one of activities and interactions (Dawson, 2010; Brown and Adler, 2008). Many subsequently argue that assessment should reflect these characteristics of learning; Whitelock (2010:5) states that it 'seems unreasonable to separate assessment from learning and for it to take place after the learning has taken place. Since learning is no longer seen as an individual endeavour, there is also a role for the learning community to have some say in this process.'

Social or collaborative learning includes a variety of activities and interactions, such as relatively informal interactions online or via study groups or more formalised collaborative activities or group performances. It is important to note that it can include the digital capture and assessing of group performance or collaboration that happens in real-life, though this section focuses primarily on assessing online collaboration and performance, as that is where the emphasis in the literature relevant to this paper appears to lie. A question common to all these activities is how to assess such interaction or collaboration appropriately, particularly because many traditional approaches to assessment focus solidly on individual – and therefore highly competitive – evaluations (Boud et al, 1999, cited in Hamer et al, 2007) . Current assessment of group activities also often focuses on academic notions of what knowledge and skills are demonstrated or, if group processes are examined, they simply reflect the amount and fairness of participation (van Aalst and Chan, 2007).

McAlpine (2012) furthers this point by describing how many assessments of collaboration either examine the behaviour of individuals or the output, but rarely assess the two qualities in tandem, which she argues is the critical element to assess yet difficult to achieve. Van Aalst

and Chan (2007) also argue that assessment of collaboration should reflect social-constructivist values that recognise individual and collective learning. Thus, this discussion raises a number of questions to explore, some of which are addressed in the literature: How do we assess the quality of collective as well as individual learning in collaborative activities? More specifically, how can assessment capture and evaluate both the output and the process of group activities, collaborations and performances? And how do digital technologies help respond to these questions?

The use of digital technologies to support collaboration is not a new area of study and has been notable in the field of computer-supported collaborative learning (CSCL), which works with collaborative enquiry using technology. Unsurprisingly, CSCL is rooted in social constructivism and includes research looking at the process of how collaborative learning happens and what is learned through it. However, as van Aalst and Chan (2007) note, little emphasis in the field has been placed on how such collaboration can be assessed and therefore the assessment of these activities can often feel incongruent, as contributions to collaboration or forums are often not evaluated. Therefore, many questions remain about the assessment of learning collectively rather than purely individually and how to align assessment with collaborative activities.

Van Aalst and Chan (2007) conducted a study that tried to merge these areas by assessing a collective knowledge building activity through the use of portfolios. The assessment of the activity was primarily done by the students themselves via self- and peer-assessment for both formative and evaluative purposes, and both the individual and collective learning was considered. Findings from the study included the following recommendations for assessment of collaborative learning: create a culture that emphasises collaboration rather than individual competition; integrate learning and assessment; hand assessment over to the students, giving agency to the students for their own and their peers' assessments; and include reflective assessment tasks that ask deeper questions rather than simple content.

Another tool supporting assessment of collaboration is social network analysis (SNA), a more recently developed methodology that examines patterns of interactions in a group or network. It analyses properties such as density, centrality, connectivity, and degrees and can visually represent both the network and the individuals within it. Dawson (2010) identifies how SNA has been used effectively to recognise what types and uses of social networks have been most beneficial for learners. However, SNA methods are not yet reliable or efficient enough to use at large scales, though Dawson also points out that improvements in data mining of social networks (e.g., discussion forums, blog posts) could ameliorate these issues, particularly relevant to online and distance learning situations.

Despite these developments, Dawson (2010:737) points out that 'there has been little attention paid to the impact of an individual student's [online] network on their learning,' including what patterns of interaction can tell us about performance or how these could be monitored and responded to. Of course, not all learners will access or benefit from networks in the same ways and not all students or teachers are knowledgeable about, prepared for or responsive to intentional networked learning. Dawson reports on a study that analysed interactions between students and staff on an HE learning management system and found that significant differences existed in the networks between students that were high performers (who tended to have stronger and bigger networks) and low performers (who tended to have smaller and weaker networks). The results showed that teaching staff interactions were more prevalent in networks of students who were higher performers and who had wider networks, when presumably, those who were low performers with narrower networks would likely have

benefitted from more tutor support. He also found that all students could benefit from accessing numerous networks but concludes:

'there is certainly evidence from the study to suggest that the “who you know” proposition is pertinent to educational contexts. Indeed, it would appear that who you know in the network is crucial not just in terms of how students come to know but the nature and quality of the knowledge they actually produce ... If teachers are enabled to ‘see’ those who are network-poor earlier in their candidature, it becomes possible for them to make timely and strategic interventions to address this issue' (747-748).

A similar point is made by Hughes (2009:292), who argues that while the use of social software like wikis or blogs can increase opportunities for participation, it can also lead to further exclusion and 'evidence also suggests that a wider range of technological options for learning benefits those who are already confident learners rather than necessarily bringing in new recruits or new approaches to learning'. She also suggests that participation in social software that involves critique or disagreement, which is often required within collaborative projects, can also conflict with the need to belong to or fit in to a community.

One relatively heavily researched example of assessment of collaborative group work is the use of wikis to map and reflect on collaborative learning, which is discussed below. A sample of technology tools used to support peer assessment and assessment of groups follows:

The use of wikis

Social software tools like blogs and wikis are increasingly found in education. They are seen to support formative assessment, increase dialogue between student groups and with the instructor, as well as develop self-reflection and assessment (Whitelock, 2010). Wikis – or websites that allow multiple users in different locations to co-create web page content – appear to be particularly suitable tools to record and demonstrate collaborative activities and are thus increasing in usage for supporting collaboration in learning, particularly in HE environments and for blended learning purposes.

However, as Barton and Heiman (2012:46) point out, 'wiki projects can fail miserably' and the challenge of assessing them are a source of regular frustration. This challenge is partly due to the vast amounts of data they can produce and also because of the irrelevance of many existing assessment rubrics, which don't account for the assessment of both content and process. Barton and Heiman (2012:46) argue that this difficulty is also what makes wikis so exciting – that they 'preserve the “archaeology” of an evolving document' and 'the discourse that goes on behind the scenes as students draft, edit and discuss those pages over the course of the project'.

The huge amounts of data can be hard to assess, even with a number of tools that have been developed to support the analysis of wikis. For example, HistoryFlow, developed by MIT, can track the progress and development of a wiki, including contributions from different authors over time. However, Rodriguez-Posada et al (2011) note that in their analysis of a number of wiki analysis tools, the most powerful ones also required higher levels of user specialised knowledge.

The use of wikis has also been promoted as supportive of learner autonomy, but it is apparent that the use of wikis does not necessarily guarantee equal or successful participation by all learners. Hughes (2009:302) argues that while social software like wikis may assess more activities in various representations, it is unlikely to unsettle current inequalities 'without

transparent assessment criteria and high quality formative feedback'. She asserts that any claims for learner empowerment through Web 2.0 or social software tools is actually unlikely to happen without a concurrent reform in the assessment system.

Examples and case studies:

- **Assessing group work fairly:** The Scottish Qualifications Authority recently developed Collaborative Learning Assessed by Social Software (CLASS) which aims to address some of the barriers to assessing evidence produced through group work fairly. CLASS is a moodle installation that includes a wiki and blog. Learners work on and are assessed together on a group project, during which they maintain a record of their learning. Both teachers and other students have access to each student's blog, on which they can comment. The increase in regular feedback from both tutors and peers was seen to encourage self-reflection and also developed into a way that conflict within the project was resolved. The transparency of the wiki resulted in learners feeling a greater sense of shared purpose and more equal responsibility, as well as a reduction in 'freeloading' that had been a problem in previous group work. (McAlpine, 2012)
- **Collaborative problem solving in virtual environments:** The EcoMUVE project works with a Multi-User Virtual Environment (MUVE) to develop activities on ecosystems in middle school science. Within the environment, various students access virtual worlds simultaneously and interact with each other and computer-based agents to undertake different collaborative activities. The activities involve notions of causality and their successful completion depends on students' logical reasoning, collaboration, and analysis and reporting skills (Winkley, 2010).
- **Collaboration through multiple choice questions:** Valdivia and Nussbaum (2007) describe a study in which students worked collaboratively on sets of multiple choice questions using mobile handheld devices in face-to-face settings. Students had to work together to reach consensus on one response they submit to the mobile device. They found that small group work in this manner enabled better participation of members than large groups did and significantly improved performance compared to a group that did not undertake the collaborative work. Challenges were identified in the investment required to create the multiple choice questions, particularly those of the caliber that would provoke debate and discourse requiring collaboration.
- **Peer and self assessment** - One method for assessing group work is via online peer moderated marking tools. One such tool, the WebPA, is an open source system developed at Loughborough University that supports peer and self assessment of group activities using assessment criteria customised by the tutor (Whitelock, 2010). A group mark is awarded based on the self and peer assessment. Both teachers and learners commented positively on the outcomes of WebPA. Teachers found the process more efficient and time-saving and learners felt the process was fair and that they gained quicker feedback and more opportunity for reflective dialogue related to the task.
- **Peer assessment** – The tool Aropa (meaning 'peer review' in Maori) has been developed New Zealand for peer assessment (Hamer et al, 2007). Students submit work or assignments that would traditionally have been solely marked by a tutor to the Aropa web site and then give feedback on others' work and receive it on theirs via the tool. In some courses, students' marks are partly determined by their participation in the peer assessment process and the feedback they provide. Evaluation of the tool shows that students varied in their responses to the process, with those in some subjects responding more positively to the process than others. Identified benefits included a better understanding of both the marking process and the topic they studied, though

some also reported feeling anxious or fearful about the process while others described it as 'unfair'.

- **Supporting formative assessment via collaboration** – As part of the REAP project discussed in section 4, a large first-year psychology class at Strathclyde University piloted a collaborative online learning scheme to add formative assessment to a course previously too large to provide such feedback (Baxter, 2007). Students were placed in small groups and each group was given small online assignments related to class lectures throughout the course. Students were required to organise division of tasks among the group and then combine individual efforts to present each assignment. The levels of engagement and quality of work exceeded tutor expectations and students were generally positive about the experience. While many found the experience stressful and more work than normal, they also said they read more on the topic earlier in the year than they would have done otherwise and learned through collaboration with others' work.

7.5 The role and use of learning analytics and educational data mining

'Big data' or the ever-increasing proliferation of data produced and available digitally offers both well publicised opportunities and less recognised threats within education. The vast amount of captured data produced by users of digital technology now leaves traceable records of online activity – through Tweets, pages read, clicks made – and culminates in data sets whose size is beyond the capability of many typical database tools. The hype around the possibilities offered by collecting and analysing this data is often touted as supportive of the democratisation of information and broader public understandings, but some critique this assertion and argue that this proliferation does not necessarily lead to greater enlightenment (Goldstein, 2012). Others have identified that the field of education gathers an enormous amount of data but is inefficient in how it deals with it, particularly in higher education (Siemens and Long, 2011). The elicitation and collection of 'big data' in education raises significant challenges in various areas: practically, in how we manage, process and interpret such large datasets; educationally, in how the data can be purposefully put to good use for learning; and ethically, in how the data is controlled, handled and protected. The field of 'learning analytics' attempts to respond to these.

The analysis of huge quantities of data – and finely grained data trails – has become commonplace in commercial and other public sectors. This use of data analysis to guide decisions and strategies can also be seen in the health care system, which is using more evidence-based randomised trials (rather than the previously common clinical practice) to help make better judgments, predict outcomes, and ultimately lead to preventative intervention. Education appears to be heading in a similar direction, emphasising 'evidence-based' data-driven decision making and improvements at classroom, national, and institutional levels. Nationally and internationally, success benchmarks are based on standardised test data and in individual schools, huge amounts of personal, interactive and academic data are captured in content management systems and virtual learning environments, particularly when learning primarily takes place online (Bienkowski et al, 2012; Ferguson, 2012). In the UK, the capturing and sharing of educational data is currently driven by school improvement initiatives and the emphasis on parental choice, as demonstrated in the emphasis on school league tables (Haggie and Brighouse, 2012).

A growing interest in the analysis of educational data has developed into the field of 'learning analytics', which is seen to be 'one of the fastest growing areas of technology-enhanced research', a trend driven by technological, political and pedagogical factors (Ferguson, 2012:2).

Interest and research activity in the field is growing rapidly, as demonstrated by the 2011 development of the Society for Learning Analytics Research (SOLAR). Learning analytics was defined by the 1st international Conference on Learning Analytics and Knowledge (LAK 2011) as:

'the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs.' (Ferguson, 2012:3)

Learning analytics includes a number of techniques for interrogating learner-based data (such as predictive modelling, user profiling, user modelling, trends analysis, adaptive learning, and social network analysis) and has branched off into various sub-categories that provide analysis and feedback to different audiences for various purposes. While learning analytics tends to focus on the interactions of learners at the class or department level, 'academic analytics' investigates and uses data at institutional, regional or national levels for high-level decision making (Ferguson, 2012; Bienkowski et al, 2012). This higher level analytics is often employed in response to national concerns about the state of a country's educational system in competition with the global world and aims to support strategies and decisions that improve results. Other offshoots include 'action analytics' and 'nudge analytics' that support change or 'prompt individuals to take action' (Ferguson, 2012: 10). One example of a project supporting 'nudge analytics' is Signals, developed by Purdue University. Signals uses large data sets to predict which students may be lagging in courses while the courses are running, in order to provide 'actionable intelligence' via a traffic signal system that helps students regulate their learning and access further help as needed (ibid).

Learning analytics is also related to educational data mining – or the use of computing techniques to find and use previously unknown data patterns in educational databases. Educational data mining tends to focus on the extraction of valuable information from huge datasets, and Ferguson (2012) notes that despite its technological base, educational data mining has historically been focused on how it could better help learners become more effective, often through the development of data-informed models that provide feedback. For example, educational data mining is often used for predictive modelling, by finding patterns and relationships within learner-centred data which are then used to probabilistically predict future outcomes. This prediction can be used to analyse student behaviour or academic outcomes. These models 'play a key role in building adaptive learning systems in which adaptations or interventions based on the model's predictions can be used to change what students experience next or even to recommend outside academic services to support their learning' (Bienkowski et al, 2012:18).

Visual data analysis is a related trend, both within education and generally (e.g., Gapminder, ManyEyes, Wordle). Such visualisation graphically represents multi-faceted complex data sets in a number of ways, including scatterplots or 3D representations. Some learning analytics tools analyse the entire learning environment in order to intervene in such a way to benefit eventual outcomes (rather than analysing what went wrong) and employ visual representations to make sense of this data. For example, some schools and universities adopt 'dashboard' systems that allow students to monitor their own academic or behavioural activity and progress and access recommendations or strategies related to individual needs and interests. Teachers may have similar 'dashboards' related to individual student or class progress that they can compare to predictive models of previous classes or performance.

Similarly, Bull et al (2006) outline the use of an 'open learner model' which is a computer-based environment that tracks a learner's progress through a course and provides regular

feedback to the student and teacher on current levels of understanding and any misconceptions. Students interact with the environment through responses to questions that create a dynamic picture that shows their progress within the topic and helps them recognise their own strengths and weaknesses. The open learner model is used in conjunction with other formative feedback and provides the information to students in various formats, including graphically or text-based. Learners can also compare their understanding with others in the class, which can help show if the topic is a particularly hard one and seemed to be a motivating factor for many students using the tool. Other findings from a pilot study using the open learner model demonstrated high levels of use of the model though its impact was not thoroughly discussed.

Siemens (2012:4) points out that while 'dashboards' and other tools that aim to support learners assess and regulate their learning can offer a sense of control, users need to know what 'good' looks like and have a solid knowledge base in order to use them effectively. Additionally, he argues that intervening in 'at risk' learning situations is not necessarily the best use of learning analytics, which instead should concentrate on overall success for all learners and 'optimization' of the learning process.

Through its various guises, learning analytics is often seen to present significant opportunities to support more effective learning and feedback. Some argue that it adopts a broader and more systemic look at learning, rather than breaking it down into measurable components in order to offer automated responses (Bienkowski et al, 2012). The ability to capture data trails to fine levels of granularity offers the chance to better understand learning processes (Siemens and Long, 2011). In this sense, it can work as a feedback loop that provides analysis of activity, patterns or performances of students so that teachers can adjust their activity or personalise additional support or learners can self-assess their own activity and its impact and make changes accordingly. Learning analytics also supports the exploration of methods of assessment that supersede the dichotomy between formative and summative assessment, in a way that can increase authenticity and agency for the learners, due to the huge variety of ways that data can be captured and reflected back to individuals. Tools that are 'learner-facing' (such as 'dashboards' mentioned above) or provide representations of the data back to learners have been seen to support self-assessment and self-regulation of learning (Siemens, 2012). While the collection and analysis of learner data allows for greater personalisation and customisation of responses and interventions, it equally raises challenges and concerns in its validity and ethics. Errors related to personalisation content or privacy-related concerns have been noted for years and been seen to materialise in various companies' privacy protection lapses (Siemens, 2012; Kobsa, 2007; Bienkowski et al, 2012).

Of course, the management and usefulness of learning analytics depends on the purpose of the tools, as well as how they are conceptualised and designed and what evidence they elicit, analyse and use. As Buckingham Shum and Deakon Crick (2012:1) state:

A marker of the health of the learning analytics field will be the quality of debate around what the technology renders visible and leaves invisible, and the pedagogical implications of design decisions, whether the design rationale is explicit or implicit. In this paper we focus on the challenge of designing learning analytics that render visible learning dispositions and the transferable competencies associated with skillful learning in diverse contexts. These are dimensions of learning that both research and practice are demonstrating to be increasingly important, but which the learning analytics field has yet to engage with deeply.

Through its development over the past decade, the field of learning analytics has slowly moved from a technological to a pedagogical focus (Ferguson, 2012). However, researchers have noted that current pedagogical models used in learning analytics tend to mirror educational priorities – such as mastering the curriculum and passing the course – and Buckingham Shum and Deakin Crick (2012) argue that too much emphasis on these priorities ignores the complexity of learners' relationships to education and risks alienating learners who are not disposed to learn. Instead, they argue for inclusion of 'disposition analytics' that examine the dispositions and characteristics important to any learning process that could help improve students' engagement with learning and support them in whatever future challenges they encounter. They draw on previous work on the dimensions of 'learning power' that can be analysed via an online self-reporting questionnaire called ELLI (Effective Lifelong Learning Inventory) to demonstrate how to model and analyse complex learning concepts like dispositions. Learners completing the ELLI questionnaire receive a visualisation of their profile of learning power, and previous research on the impact of ELLI depicts positive changes in learners' attitudes and perceptions of their own learning. This use of visual analytics is particularly apt for multi-dimensional frameworks like ELLI, and Buckingham Shum and Deakin Crick (2012) argue that such visualisations can be useful for both teachers and students.

In a similar vein and as previously discussed, social network analysis is drawn from socially constructivist perspectives to investigate social networks, their actors and their relationships (Dawson, 2010; Ferguson, 2012). A related branch of analysis is social learning analytics, which focuses on learning that happens in participatory online cultures. While some researchers are beginning to examine these areas, the learning analytics research and development community has yet to comprehensively address how to model and analyse these complex concepts. As a quickly emerging research field, the effectiveness of learning analytics also partly depends on increased communication and knowledge sharing among developers, researchers and those using learning analytics tools. Siemens (2012) highlights the current isolation of researchers from vendors and practitioners working with learning analytics, which leads to gaps between research and practice. This is complicated by the prevalence of innovation within the vendor sector, where new tools and practices are rarely open and transparent for testing by researchers, though the R project (<http://www.r-project.org/>) and collaboration at learning labs like the Pittsburgh Science of Learning Center's Data Shop are notable exceptions (Siemens, 2012; Bienkowski et al, 2012). Siemens (2012) also points out the commercial sector may not have the same interests as researchers in understanding the use of analytics from the perspectives of organisations, practitioners, and learners, as well as investigating the overall context.

With tools becoming more powerful and data mining and analysis practices becoming more widespread, ethical issues and questions are of great concern, particularly in relation to control and management of such large data sets. Bienkowski et al (2012) discuss the range of ethical implications learning analytics presents, highlighting data protection, ownership and privacy issues, particularly in educational contexts where institutions are required to maintain privacy of its learners and teachers. While the analysis of assessment information can prove a useful tool, learners and teachers may equally wonder how secure and protected the data is and who else may have or eventually be able to gain access to 'models of what they know and don't know' (Kobsa, 2007). Though not significantly discussed in the literature, much of the data collected on learners appears to happen without consent or without much discussion on who owns it, how it will be used and what protections will be put in place to secure it and protect students' privacy. Many of the questions raised by these issues, particularly around what data we actually want to collect and, equally important, what do we

not think is ok or desirable to measure, underpin the development of tools and resulting practices.

Many countries enforce varying types of data protection laws, and this particular issue has begun to be recognised by various governments, if somewhat superficially. For example, the US recently launched education.data.gov, a website hosting huge amounts of education-related data and aims to include a 'MyData Button' that offers students and their parents 'secure, timely and electronic' access to education transcripts and records, seemingly a nod to learner control or individual use of data (Office of Science and Technology Policy, 2012). However, Siemens (2012:3) argues that these issues must be confronted and made more transparent by those working within the sector, partly because a lack of clarification on learner rights and data ownership could lead to 'learner, and even broader public, pushback to learning analytics as a field'.

Additionally, as more and more information is collected and used to predict learners' performances and learning trajectories, questions around ethical responsibilities arise: How do we ensure predictive models are valid and reliable? How can information be shared and depicted in ways that benefit and enhance the learning process? How do analytically determined predictions of learning outcomes support formative processes of learning, rather than simply summative assessments of whether or not students are on the predicted track? Does 'predictive analytics' trade the potential aspirations and achievements of developing learners for self-fulfilling benchmarks of predicted learning outcomes? These questions are especially pertinent when considering research findings that show how 'culturally transmitted beliefs about "the fixity of ability" have a direct, deleterious effect on students' willingness to persist intelligently in the face of difficulty (Dweck, 1999, cited in Claxton 2009: 179).

While these ethical concerns are often mentioned in reports and research papers, they rarely seem to be the focus of them. Questions related to ownership, privacy and confidentiality of educational data, as well as consent for collecting and using data, deserve significantly more attention and investigation than currently allotted, given that the 2012 Horizon Report lists 'learning analytics' in the 2- to 3-year range for widespread adoption (Horizon Project Shortlist 2012, cited in Bienkowski et al, 2012). While learning analytics currently tends to be focused in higher education, the schools market for them is also developing, which will raise additional ethical issues around consent. Indeed, education is already significantly attracting vendors and companies developing data mining and analytics tools that are powerful commercial bodies but that may not specialise in understanding pedagogical implications or benefits of tools. It is possible that if researchers and practitioners do not drive the development of learning analytics tools and purposes, the field's commercial branch will. While innovation via commercial means is not necessarily a bad thing, it opens the possibility that development is not pedagogically led to analyse and improve the process of learning and instead becomes simply another method of performance measure.

Finally, Bienkowski et al (2012:38-39) remind us of the essential element of human judgment, which can be 'underemphasized' but which plays a critical role in determining what data to capture, interpretation of data and deciding what actions to take based on the outcomes. In this sense, 'data mining and analytics technology play a supporting role in the essentially human and social effort of making meaning out of experience ... Data mining and analytics do not give answers when just unleashed on a big data warehouse'. Siemens (2012) furthers the point by arguing that learning analytics needs to move further from its orientation to technology to one that translates the data into making decisions and taking informed action – in essence, making a shift from development and research to practice.

Across and beyond the curriculum, digital technologies are changing what is being taught and learned, how that process happens and what students are expected to know and demonstrate. However, many argue that educational institutions appear slow to catch on or catch up when it comes to assessment, despite growing agreement that assessment needs to be more closely linked to learning theory, embedded within teaching and learning and acknowledge new digital practices (Whitelock, 2010). Many assert that current schools are not adequately preparing our children for the future and they leave their formal education ill-prepared to tackle complex problems in the real world (Shute et al, 2010). Gee and Shaffer (2010: 4) suggest that it is the assessment's system focus on standardised tests that impedes schools from 'entering the 21st century in our classrooms'. These educational challenges seem daunting but also present a prime opportunity to consider how to develop an assessment system that responds to these changes and reflects broader educational goals.

However, an imperative to reform the assessment system begs the question of what revolutionary outcomes are desired. It primarily requires an articulation of the improvement – what 'transformation' of assessment would be valuable and for what purpose? In this sense, it is vital to remember that assessment systems and practices – as well as the tools and technologies that support them – are designed to suit certain purposes and outcomes and as driven by various trends and influences. The discussion about the affordances of new technologies inevitably raises questions about what that design should look like.

The potential that technology offers provokes fundamental questions about how we approach assessment. If we are, as Pellegrino & Quellmalz (2010) argue, to create a 'new generation of assessments' and '21st Century approaches to assessment', what do we hope them to look like? How do we conceptualise what assessment should measure and how it should be done? What type of learning should we capture? Surely these should reflect educational goals and the type of learners a society wishes to cultivate. They should also account for a changing world and participation of learners and depict an understanding of the competencies, knowledge, skills and dispositions they need to flourish. Any evaluation of what digital technologies offer assessment must first grapple with these questions and articulate a position.

Reflection on the literature and research reviewed, including the case studies and examples of new tools and practices can provide some insight into how this could happen. Based on the questions this review has raised, a number of areas of future research and discussion are suggested, in an effort to start new conversations that can begin to answer them. Research into these areas should support dialogue around the broader purpose of assessment, as well as what is assessed and how that happens. These recommendations have been synthesised from themes gathered in the review, as well as questions raised throughout the review process:

- **Cultivate new assessment practices based on principles and theories of learning**

This involves integrating relevant and recent understandings of learning, and in particular the role of feedback and assessment, into principles and then practices. Hattie and Brown (2007-2008) demonstrate how this can be done within a framework of national assessment. It also requires a more thorough understanding of what constitutes effective feedback. If a core educational aim is to improve learning, we should be using assessment practices that deliver this based upon principles developed alongside robust and valid research. As Draper (2009a: 286) suggests, we should 'judge assessment techniques in terms of the learning gains associated with them.'

- **Develop new assessment tools that reflect pedagogical principles**

There is an acknowledged need for a 'pedagogically driven model for e-assessment that can allow students to take more control of their own learning and become more reflective' (Whitelock and Watt, 2008: 152), as opposed to this being driven by technology. This aligns with the growing understanding of the importance of self-regulated learning and peer assessment but is challenged by the emphasis on summative assessment from many sectors, including political and commercial ones. This area applies to tools used in the classroom as well as those for analysis purposes and links to discussions of cost of new technologies and tools, an area rarely explored, as well as collaboration between developers and educators. There is tension in determining what drives development in this area and concerns that technology developers will take the lead without significant regard for pedagogy or learning outcomes, as demonstrated in the shifting focus of e-portfolios software documented earlier. This raises the question of how public and private sectors work together effectively and how practitioners and technical and software developers ensure that tools match the learning goals and purposes.

- **Construct new responses to the current emphasis on high-stakes summative assessment.**

Technology enhanced assessment is likely to prove harder to introduce in the context of summative assessment such as external public examinations. However, the potential for greater efficiency and effectiveness in this context is considerable making this application of e-assessment an urgent focus for more research and development.

- **Merging the activities involved in curriculum, instruction and assessment offers the opportunity for assessment to take a more central and regular role in learning,**

This in turn supports those in school to use and practice their skills and knowledge to solve real-life problems outside the classroom walls and in different contexts (Gee and Shaffer, 2010). This area also includes the integration of formative assessment within multi-level summative assessment and is well explained by Pellegrino and Quellmalz (2010: 132):

'Extensive technology-based systems that link curriculum, instruction, and assessment at the classroom level might enable a shift from today's assessment systems ... When we implement powerful technology-based systems in classrooms, rich sources of information about intellectually significant student learning will be continuously available across wide segments of the curriculum and for individual learners over extended periods of time. This is exactly the kind of information we now lack, making it difficult to use assessment to truly support learning.'

- **Investigate how digital technologies can support fairer, more equitable, and democratised assessment methods**

As discussed within the review, some practices may make technology enhanced assessment (TEA) more accessible and comfortable; others may be divisive or exclusionary. Analysis of many tools demonstrates that 'innovations' and new technologies do not change power relations. Barton and Heiman (2012) discuss how despite claims to the contrary, use of wikis for collaboration does not flatten hierarchies; Dawson (2010) demonstrates how use of online networks often replicates the types of social and educational connections students have offline; and Jenkins et al (2006) discuss the 'participation gap' that depicts the spectrum of actual digital participation and production by young people. Hughes (2009:298) warns that we must avoid the rhetoric of learner empowerment through tools like social software, as 'the danger here is to assume that changing the 'delivery' challenges the 'essence' of learning. It might, but there is no guarantee that the more disadvantaged learners will benefit socially or operationally from more autonomy and 'choice' of technologies'. The challenge is then to support learning and assessment that

unsettles existing hierarchies in participation and learning and provides a genuine platform for learners to be active agents who are more in charge of their learning. This includes considering how technology enhanced assessment practices promote or constrain accessibility for different students, particularly those who do not succeed in more academic educational environments, which could be investigated through research looking at students' experiences or perspectives on assessment, a seemingly under-researched area. Finally, as Facer (2012:98) argues, young people tend to be presented with futures where the options open to them and skills they need appear predetermined and 'the potential for young people to challenge, question or reshape the futures they are being offered is invisible'. In what way, then, can assessment practices and principles open up new dialogue and offer real choices that support young people to collaborate in the creation of their futures rather than create rigid structures they must follow in order to get there?

- **Respond to ethical challenges presented by the use of digital technologies in assessment**

Recognising that the utopian discourse on technology in education also has a slightly darker side involves challenges related to 'big data', consent, data protection, ownership and control of information, as well as the ethical responsibilities educators have towards young people. Additionally, it raises another 'ethics challenge,' asking how media education will address the inevitable new dilemmas emerging from new digital practices (Jenkins et al, 2006), which cross over into related ethical issues in assessment. How do we deal with new online identities, both real and assumed? What are the implications for data protection and ownership of making, mixing and publishing media online?

- **Consider new contexts relevant to assessment using digital technologies, including learners' lives and social, cultural, educational and technical backgrounds**

It is relevant to recognise and consider the range of new contexts related to learning, assessment and use of digital technologies. This involves the new contexts, practices and cultures that face young people, as well as the changing contexts of educational provision. There is a growing prevalence in young people's lives to use, create and collaborate through digital technologies at ever-increasing rates and as normal daily activities. These cultures have major implications on learning and assessment, in terms of considering what knowledge and competences should constitute instruction and evaluation, how to support all young people to access supportive networks and how to assess activities emerging from this culture, such as knowledge-building and collaboration (Wasson and Void, in press). Additionally, within this review, the context has been mainly within Western cultures and a high proportion of the discussion has centred on higher education practices. Further research should also recognise the potential differences and uniqueness of the use of digital technologies for assessment in other cultural and educational contexts.

Further investigation of these areas (and no doubt others) aims to reignite discussions around assessment. In the process some fundamental questions about how schools and universities capture and evaluate their students' learning and progress, with or without the use of digital technologies should be asked. Changes to assessment are risky, because reassessing its fundamental properties and principles also calls into question deeper aspects of education, not least of which is the relationship and roles between learners and teachers. However, these discussions can help, as Gee and Shaffer (2010: 6) suggest, reassess three fundamental properties of assessment that need rethinking: 'what is assessed, how the assessment takes place and the purpose of the assessment in the first place. In other words, nearly everything.' While it is clear that technology has the potential to be a force for change across a spectrum of optimistic and challenging responses related to assessment, perhaps its most effective role is as a prompt to rethink the way assessment happens now and in the future.

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