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Technology Enhanced Formative Assessment for 21st Century Learning

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ABSTRACT

This paper is based on the deliberations of the Assessment Working Group at EDUsummIT 2015 in Bangkok, Thailand. All of the members of Thematic Working Group 5 (TWG5) have contributed to this synthesis of potentials, concerns and issues with regard to the role of technology in assessment as, for and of learning in the 21st century. The group decided to focus primarily on formative assessment rather than summative assessment and high stakes testing. Formative assessments and feedback provide an important opportunity to support and enhance student learning. Recognizing shifts in education towards blended and online learning with problem-based and inquiry-based approaches led to considerations of technologies that could effectively support formative assessment and informative feedback to 21st century learners. The paper concludes with a summary of conclusions and recommendations of the working group to be taken up in subsequent efforts.

Keywords

Formative assessment, Inquiry-based learning, Problem-based learning, Summative assessment, Technologies for assessment

Introduction

The importance of formative assessment in student learning is discussed at various levels in the context of teaching and learning environments. With the known purpose of assessment in education being to support learning, some educational reforms clearly recognized the significance of formative assessments and feedback (Black & William, 2006; CDC & HKEAA, 2007). Brown, Hui, Yu, and Kennedy (2011) also have highlighted the importance of teacher cooperation and staff development to initiate the changes to formative assessment and feedback. In Hattie's (2009; 2012) research on visible learning, formative assessment was rated as one of the most effective methods to encourage student achievement. Wiliam, Lee, Harrison and Black (2004) also found that integration of formative assessment into teaching resulted in enhanced student performance. Bulunuz et al. (2016) indicated that formative assessment creates opportunities to promote the development of student's skills of explaining, interpreting and reasoning. Narciss (2008) provided a comprehensive overview of the benefits of timely and informative feedback (i.e., formative assessment). The shift in pedagogy towards dynamic problem-based and inquiry-based learning is gaining increasing attention as a means to support the development of 21st century skills (Lu, Bridges, & Hmelo-Silver, 2014; P21, n.d.), and this creates a need for changes in formative assessments. The opportunities to use technology to support formative assessment for learning have also grown with the development of new learning technologies (Johnson et al., 2016; Woolf, 2010). For example, recent review identified how various technological affordances are being integrated into the next generation of problem-based designs, to enhance both online and face-to-face interactions and collaborative knowledge building (Jin & Bridges, 2014; Narciss, 2008; Roskos & Neuman, 2012). This paper discusses some of the current issues with formative assessment and considers how the tools and technologies that are available can develop new formative assessment practices to support 21st century learning (P21, n.d.). The paper concludes with trends, directions and general conclusions emphasizing the significance of formative

assessment along with recommendations for future research and development in this area consistent with the emphasis on 21st century skills and new technologies.

Formative assessments and current issues

Davis (2015) highlights the importance of formative assessment, as it is critical to a teacher's ability to adapt lessons and check for student understanding. Under the umbrella term of assessment, formative assessment refers to the appraisals of student performance intended to help learners attain intended goals as distinguished from formative evaluation, which refers to judgments about how to improve program effectiveness as an effort evolves over time (OECD, 2005). Formative assessment is also defined as assessment *for* learning (Bennett, 2011) because the emphasis is on forming judgments about learners' progress that then affects the subsequent flow of instruction, whereas summative assessments have been viewed as focusing on making judgments about how well individuals did at the end of an instructional sequence, which might be considered assessments *of* learning (Ecclestone, 2010). Because formative assessments, in the form of timely and informative feedback, are aimed at helping learners improve, formative assessments can be considered a form of learning or assessments *as* learning (Spector, 2015). According to Sadler (1989) formative assessments involve making judgments about the quality of students' responses and using those judgements immediately to guide and improve students' understandings and skills. In the current context of teaching and learning, Ecclestone (2010) argued that formative assessment or assessment for learning is now considered an integral component to good teaching, student motivation, engagement and higher levels of achievement, and that view has been supported by many others (see, for example, Johnson et al., 2016; Narciss, 2008; Spector, 2015; Woolf, 2010). Also, timely and informative feedback (also known as formative assessment) is known to enhance and expedite learning (Bransford, Brown, & Cocking, 2000; Clariana, 1990; Epstein et al., 2002; Hannafin, 1982; Kluger & DeNisi, 1996; Narciss, 2008). Formative assessments are usually determined by teachers or automated learning environments, allowing them to be directly controlled by a teacher or a learning management system. However, when learning tasks involve critical thinking and complex problem solving, determining relevant feedback for learners becomes more challenging and time consuming. Sometimes, overemphasis on summative assessments such as grades, standardized test scores, comparative rankings and annual performance ratings have resulted in too little emphasis on and support for formative assessment providing individualized and constructive feedback during learning (Baker, 2007; Ecclestone, 2010; Harlen & Deakin Crick, 2002; Sadler & Good, 2006). In the presidential address to the American Educational Research Association, Eva Baker (2007) argued that tests should generally be used to help teachers and learners improve individual learning (formative assessment) and to help administrators and policy makers identify areas in need of improvement (formative evaluation). One issue, then, concerns the need for additional focus and emphasis on formative assessment.

A second issue involves sources of formative assessments. The one-way route of feedback from teacher to student is not the only way to provide feedback for students to improve their learning. Both self-assessment and peer-assessment can be meaningful forms of formative feedback. The feedback from a student about his or her own performance or feedback provided to other students about their performance is often sufficient for students to improve their work (Ecclestone, 2010; Ross, 2006). Peer- and self-assessments then comprise a major form of assessment *as* learning. Webb, Gibson, and Forkosh-Baruch (2013) argue that combining evidence-centered design (Mislevy, Steinberg, & Almond, 1999), formative assessment frameworks (Black, Harrison, Lee, Marshall, & Wiliam, 2004) and the use of computerized assessments can harness learning experiences for both teachers and students. The integration of evidence-centered design, formative assessment, and automation assists the development of their evaluation and validation processes through technology-enabled assessments to address simultaneously, assessment *for* learning and assessment *of* learning. Sadler (1989) argued that for students to be able to improve they must develop the capacity to monitor the quality of their own work by learning to appreciate high quality work along with the knowledge and skills to be able to compare their work against high quality work (i.e., effective self-assessment). Self-assessment can foster and strengthen meta-cognition and self-regulation skills that are important learning skills (Bransford, Brown, & Cocking, 2000).

A third issue involves the so-called 21st century skills (P21, n.d.). While 21st century skills are discussed by many educators in a variety of contexts, the Partnership for 21st century Learning (P21) provides a framework that captures most of what is being said about these skills in terms of four clusters: (a) key subjects and themes (e.g., global awareness and multiple literacies, such as financial, civic, health and environmental; (b) learning and innovation

skills (e.g., creativity and innovation, critical thinking and problem solving, communication and collaboration); (c) information, media and technology skills (e.g., information, media and ICT literacy); and (d) life-long learning and career skills (e.g., adaptability, initiative, social skills, accountability and leadership). P21 stresses the need for ongoing formative assessments throughout a learner's education to develop those skills. Many of these skills and the need for assessing them are emphasized in other sources (e.g., Bransford, Brown, & Cocking, 2000; Johnson et al., 2016; Woolf, 2010). In this paper, we focus on a few that we believe are especially challenging and critical – namely, critical thinking and problem solving (Bulunuz et al., 2016; Spector, 2016) as they are connected with nearly all of the other P21 skills as well as with new technologies which are discussed in the next section.

There are additional issues that present challenges for formative assessment. One situation that present a challenge for timely and meaningful assessments include large and multi-grade classrooms backgrounds, especially in developing countries (Wagner, 2011). Another challenging situation involves filtering and managing the wealth of resources, data, services and technologies available at little or no costs on the Internet (Spector, 2016). These additional issues are touched upon in a subsequent section but remain ongoing issues to be addressed by researchers, developers and educators to wish to realize the full potential of formative assessment and new technologies.

Formative assessments in technology-enhanced learning

Ellis (2013) and others note that in the past one of the key limitations of improving formative assessment was that the vast majority of courses were delivered face-to-face and that prevented capturing the learning interactions and outcomes into a system for identification and analysis of formative feedback and assessment. However, in the 21st century and with new technologies, there are multiple opportunities to capture both performance and assessment data and analyse them to understand how students are progressing with various forms of activities and then determine what adjustments might be made to help different learners (Bichsel, 2012). Some automated systems are capable of capturing such data; however, it is the effective use of those data that will have a positive impact on learners and teachers (Spector, 2014a; Spector, 2016). Learning analytics projects that are spread across various educational institutions can provide closer identification of learner habits and key areas that need additional support for progressing with learning (Siemens & Baker, 2012). The analysis of large data sets containing information about student learning and performance has significant potential to impact formative feedback as well as the design of instruction and educational practices and policies (Spector, 2016).

Other educational technologies mentioned by the New Media Consortium and other groups include MOOCs (Massive Open Online Courses), Serious Games and Gamification (Spector, 2014a; Hooshyar et al., 2016; Johnson et al., 2016; Woolf, 2010). These new technologies have the ability to generate and make use of large sets of data. As indicated by Ellis (2013), Bull et al. (2014) and Colvin et al. (2015), these data sets can be used to represent learning patterns, areas in which students need improvement, and likely interventions to be considered by a teacher or teaching system. Making use of big data requires sophisticated learning analytics applied to performance and assessment data collected from many different learners in a wide variety of learning situations (Spector, 2014a; Spector, 2016). Moreover, formative assessments can motivate individual learners, help teachers adjust individual learning paths, and inform parents and others of progress (Spector, 2016). From a learning perspective, there are clearly links between engagement, efficiency and effectiveness (Spector & Merrill, 2008). From a design and systems perspective, there are clearly links between interaction, integration, and intelligence. When learning becomes inefficient, slow or tedious, learners tend to lose interest. Integrating resources, technologies and activities can contribute to efficiency and keeping learners engaged. Using intelligent and adaptive technologies tend to sustain interest and engagement.

In addition to providing the means to support personalized learning and a smart education system responsive to the needs of learners and teachers and their learning environments, new technologies can support key 21st century skills discussed in the previous section – notably critical thinking and problem solving. Along with the development of 21st century skills, emphasized has been placed on specific domains – notably the so-called STEM disciplines (science, technology, engineering and mathematics). That emphasis is evident in many of the sources already cited (e.g., Johnson et al., 2016; Woolf, 2010) and is reflected in new standards such as the Next Generation Science Standards that emphasis the integration of engineering into science learning (see http://www.nextgenscience.org/). Such emphasis is consistent with advances in pedagogical approaches such as anchored instruction (Bransford et al., 1990), inquiry learning (Linn & Eylon, 2011), and problem-based learning (Hmelo-Silver & Barrows, 2000), along

with the ability of new technologies (e.g., augmented and virtual reality, context aware sensors, and automated feedback mechanisms) to support those approaches in the form of inquiry- and problem-based learning. The ability of new technologies to provide support for formative assessment has risen considerably in recent years with the advent of intelligent agents (Ehimwenma, Beer, & Crowther, 2014; Greer, & Mark, 2015; Harley et al., 2015), smart devices (Shorfuzzaman et al., 2015; Spector, 2014a; Spector, 2016) and cloud-based resources (Armstrong, & Llorin, 2015). These and other developments will be taken up in a subsequent section. Next we discuss new technology-enhanced learning environments and environments that create new demands for timely and informative feedback.

Formative assessments in the form of timely and informative feedback can support effective problem-based and inquiry-based learning that is especially sensitive to and dependent on formative feedback to learners (Salomon & Globerson, 1987; Shute, 2007). A particular approach to such support in a dynamic and online learning context will be discussed in the next section. That approach involves eliciting how learning is thinking about a challenging problem or inquiry process, and then generating both directive and suggestive feedback automatically to help the learning succeed in finding a suitable resolution to the problem situation. Before discussion that and other new approaches, the issue of open resources and the general purpose of formative assessment in a technology intensive environment require further comment.

The use of Open Education Resources (OERs) that are free online learning materials accessible to anyone across the world for teaching and learning purposes can be used to enhance formative assessments. The multitude of open education resources available to support learning can only be fully realized when coupled with meaningful formative assessments, especially in areas involving critical thinking skills. As the use of OERs spreads, emphasis on digital literacy becomes increasingly important. Not everything that is openly accessible is reliable or easily found. Moreover, there are associated reasoning skills pertaining to the selection, validation and use of open resources that might be considered basic skills that also require the support of new assessment strategies and techniques. Supporting learning in a connected world in which students have easy access to rich sets of data and information is a new and challenging area for formative assessment. New tools and technologies for formative assessments can be used to leverage OERs and eventually also create open assessment repositories that could been be mined using learning analytics to design learning scenarios as well as personalize learning experiences for individual learners.

To conclude this section on assessments in technology-enhanced learning situations, we wish to emphasize several points. First, nearly all learning environments in the 21st century involve and depend on digital technologies, such as computers, hand-held devices, the Internet, internet whiteboards and so on. As a result, the purpose of formative assessment has not changed on account of new technologies. Rather, the significance of formative assessment has grown on account of new technologies and 21st century learning demands. As more and more learning activities involve the internet, the timeliness of feedback becomes increasingly important. A week's or even a day's delay in proving feedback can jeopardize the effectiveness of the feedback in terms of improving learning and performance. Providing such timely and meaningful feedback without making use of advanced technologies is difficult to imagine. Those possibilities are discussed in the next two sections.

As a closing reminder to this section, it is worthwhile to recall the key purposes of formative assessments identified by Ecclestone (2010): (a) determine starting points and current knowledge levels of learners, (b) identify strengths and weaknesses of learners in relation to desired learning outcomes, ((c) review the learning progress of individual learners, (d) set targets and goals for future efforts, and e) guide and advise individual learners to address their weaknesses and build on their strengths and interests. While a formative assessment supports those five areas, the primary purpose of formative assessment is to help learners attain intended goals, which involves indicating weaknesses and deficiencies while encouraging specific activities and approaches to promote engagement and address weaknesses. The outcomes of formative assessments should enable teachers to make instructional decisions and enable students to set goals, allow students to evaluate their performance and change their approaches to learning, while actively engaging the students in their learning; improving their skills and knowledge; motivating and allowing students to become independent learners (Crookall, 2010; Eccelestone, 2010; Slavich, & Zimbardo, 2012). As indicated earlier, as formative assessments are emphasized and developed for challenging situations (large and multi-grade classrooms, inquiry- and problem-based learning), there is an opportunity for technology to play a key role in formative assessment. Recent studies in technology-enhanced problem based learning (PBL) have indicated the continuing centrality of the teacher or tutor in facilitating feedback whether in blended environments (Bridges et al., 2015), online meeting technologies (Ng et al., 2013) or virtual learning environments (Savin-Baden et al., 2015).

New trends and directions in formative assessments in technology enhanced learning

In this section, a few representative formative assessment efforts in a number of technology-enhanced learning contexts are discussed in this section which is far from exhaustive. General conclusions are addressed in the next section followed by a number of recommendations.

Formative feedback mechanisms

Technology can be used to support formative feedback in many different ways. In general, one can conceptualize formative feedback as one form of scaffolding for learners. The simplest scaffolds provide feedback based on the performance of a learner on a specific learning task, as was done in various intelligent tutoring systems. That form of feedback requires a database containing the subject to be learned along with common problems encountered with links to remediation. Automatic direction to a question and answer database based on a learner response is another simple formative feedback mechanism. Such mechanisms already exist and can be expanded. While those mechanisms still have appropriate uses, their application is generally limited to very well defined domains and straightforward learning tasks.

More advanced mechanisms depend on additional information about learners that goes beyond their performance on a specific learning tasks. An effort at the Hong Kong Institute of Education aligned to formative assessments with individual differences and formative feedback orientation (Yang, Sin, Li, Guo, & Lui, 2014). To gain a deeper understanding of the impact of formative feedback orientation on students' learning, they took account of students' important goal orientations: (a) performance goal orientation, and (b) learning goal orientation. Yang et al.'s (2014) findings indicated that students with a learning goal orientation (e.g., master that learning tasks) were more likely to find teacher feedback useful and feel personally responsible to respond to teacher feedback (i.e., high accountability of implementing feedback) than those with a performance goal orientation (e.g., get a desired grade).

When a robust and dynamic learner profile is available that includes interests, biases, preferences, as well as performance data, then feedback can be generated either by a teacher or by a smart learning engine that leverages those characteristics in suggesting next steps and resources to explore. Such an intelligent feedback mechanism has yet to be deployed on a large and sustainable scale, so it is one of the recommendations mentioned in the final section.

Formative feedback for problem-based and inquiry learning

Ongoing research in technology-enhanced problem-based learning (PBL) in health sciences education are now aimed at integrating multiple approaches to learning activities and formative feedback (Kazi, Haddawy, & Suebnukarn, 2009). These designs employ multimodal problems, scenarios, or/and cases (videos, 3-D imaging) in re-designed physical and virtual learning spaces. In this new iteration of the traditional PBL format, students collaborate in face-to-face groups via mobile devices, interactive whiteboards and online resources (including open educational resources) using collaborative tools and concept mapping software. Findings are indicating new opportunities and challenges for PBL designers and facilitators in scaffolding deeper approaches in blended PBL environments (Bridges, 2015; Chan et al., 2012; Chan et al., 2015) including harnessing the potential of new digital texts in supporting visual semiosis across the PBL cycle (Bridges et al., 2015). Of course PBL has extended far beyond medical education and training and these approaches are generally applicable in any PBL context.

Formative feedback for ePortfolios

ePortfolio tools are increasingly used to support PBL, inquiry learning and other subjects and are now embedded within learning management systems (Fisher, & Hill, 2014); they provide a holistic approach to recording achievements (Bell, & White, 2013; Ambrose, & Chen, 2015) and providing formative assessment in line with professional standards. While many institutions are still working through the known challenges in relation to ePortfolios (Gibson, 2006), learning management systems and other learning technologies have provided elegant solutions (Smart, Sim, & Finger, 2015; Brown, 2015). While ePortfolios provide opportunities for authentic

formative and summative assessments, they require significant human time with regard to feedback and assessment (Smart, Sim, & Finger, 2015). While ePortfolios are promoted for their potential benefits to teaching, learning, assessment, and curricula, they are seen as especially useful for extending and deepening assessment value (Ambrose & Chen, 2015; Fisher & Hill 2014). However, empirical research into ePortfolio initiatives suggests the complexities and challenges are significant. One obvious challenges involves the variety of information types and representations that comprise portfolios (text, graphs, links, audio, video, images, etc.). There are also issues involving privacy and intellectual property rights. In addition, it is not clear that large collections of ePortfolios will be available for use within the context of an intelligent assessment system, so this is another area recommended for further exploration.

Formative feedback to improve motivation and engagement

When it comes to developing knowledge and skills in complex and challenging domains (discussed next), issues pertaining to motivation and engagement emerge as important feedback areas. The reality is that motivation and engagement are important areas to support with formative feedback in nearly every learning situation because there is a clear link between motivation, engagement, time-on-task and learning outcomes (Keller, 2009). While several learning technologies and tools support engaged learning and formative assessments, promoting student engagement and motivation has become challenging with regard to complex learning tasks and in developing countries for large student cohorts with limited resources. A group of academics at the Sri Lanka Institute of Advanced Technological Education (SLIATE) have been experimenting with new teaching and assessing methodologies; combining team-based learning and guided inquiry learning (Lokuge Dona & Gregory, 2015a; Lokuge Dona, Gregory & Pechenkina, 2016). The assessments are designed in accordance with established pedagogical principles (e.g., provide scaffolding according to individual learner needs) so as to initiate discussion among the academics about the key concepts related to the unit, to identify a strategy to embed the idea and to identify the suitable technology for a successful implementation (Gregory & Lokuge Dona, 2015; Gregory, Lokuge Dona & Bailey, 2015). This approach has enabled SLIATE staff to provide an engaging learning experience and develop a collaborative work environment, representing real world situations while integrating digital assessments (Lokuge Dona & Gregory, 2015a). The ability to provide immediate meaningful feedback has facilitated significant improvements in learning. However, substantial training and mentoring of teachers with a change management process is required for successful implementation on a larger scale (Lokuge Dona, 2015; Lokuge Dona et al., 2015b), which is discussed more generally in the section on teacher training below.

Tools for complex learning

As mentioned in the discussion of 21st century skills, critical thinking is key to success in a number of areas in which inquiry- and problem-based approaches are appropriate. Within those approaches, complex learning tasks are frequently involved - that is, tasks that are somewhat ill-defined and that lend themselves to multiple solution approaches and acceptable solutions. It is precisely in such areas that critical thinking is important to develop, and those tasks tend to recur throughout a person's life in both job and personal contexts. The most promising recent advances in providing meaningful just-in-time, just-when-needed formative assessment for complex learning tasks involve a series of research efforts in Germany and the USA and tools that were consolidated in Highly Integrated Model Assessment Tools and Technology (HIMATT; Ifenthaler, 2010; Pirnay-Dummer, Ifenthaler, & Spector, 2010; Spector & Koszalka, 2004). HIMATT provides a learner with a problem situation and then prompts the learner to indicate (in the form of text or an annotated graph) the key factors and their relationships involved in addressing the problem. This problem conceptualization can be compared to an expert conceptualization or reference model and analysed to indicate things for the learner to consider (Ifenthaler, 2010; Pirnay-Dummer, Ifenthaler, & Spector 2010; Spector & Koszalka, 2004). A further development of HIMATT is AKOVIA (Automated Knowledge Visualization and Assessment; Ifenthaler, 2014). These formative assessment tools require refinements and user-friendly interfaces to be used in face-to-face and online settings. The tools were originally developed for research purposes and have now been shown to be effective and useful in more than 15 research studies. However, to be converted into formative assessment tools for use by teachers, a number of enhancements need to be made (Ifenthaler, 2011; Shute, Jeong, Spector, Seel, & Johnson, 2009). First, a way for teachers to easily enter representative problems and to develop reference models based on their own responses and those of recognized domain experts. Second, a decision algorithm needs to be included that determines which parts of a reference model might be suggested to a learner for consideration or whether and when to show the entire reference model and prompt a learner for a comparative

analysis. This research needs further development and enhancement to create a new version based on the currently validated methodology for educators to be able to use it.

Adaptive formative assessment

Computer-assisted learning environments made use of branching based on learner interactions that were the same for all learners in that same situation (Wauters, Desmet, & Van den Noorgate, 2010). Intelligent tutoring systems were a step forward but once a learner had been profiled with a specific deficiency in the learning environment, the remediation was again the same for all learners with that particular deficiency (Spector, 2014a; Spector, 2016). Those systems were static with regard to the knowledge domain and feedback mechanisms involved. However, with the development of new learning technologies, large sets of data, learning analytics and advanced artificial intelligence tools more can be done to create dynamic formative feedback systems (Murray & Pérez, 2015; Spector, 2014a; Spector, 2016). As discussed by Tyton Partners (2013), an adaptive learning system is capable of creating a personalized learning experience that employs a sophisticated data-driven, often non-linear approach to instruction and remediation, that adjusts to a learner's interactions and demonstrated performance level, and subsequently anticipates types of content and resources learners need at a specific point in time to progress (Ifenthaler, 2015; Pirnay-Dummer, Ifenthaler, & Spector, 2010). MathSpace, an adaptive learning system for mathematics that was piloted at Swinburne University of Technology showed great results in supporting students in their mathematical skills (Alao, Lee, O'Kane, & Jackson, G, 2016). This system enables hand writing recognition with all mathematics problems, allowing learners to undertake different mathematical questions with immediate feedback at each stage of the solution. As Hattie and Timperley (2007) argued, ongoing or frequent feedback, especially feedback that was visible to both learners and teachers, has a significant impact on learning. In the MathSpace system, the students are guided with feedback for each step in mathematical problems, facilitating the development of students' understanding on how to improve. Intelligent systems are now capable of dynamically providing questions that will support the students' learning based on the learner's capabilities (Malekzadeh, Mustafa, & Lahsasna, 2015). Smart Sparrow is another authoring tool that several international and Australian higher education institutes use to create a dynamic learning environment to support different learning styles. This also facilitates real-time dynamic mapping and sequencing of instruction to match individual learner characteristics.

Massive online formative assessment

Providing an engaging learning environment with timely feedback to the learners plays a major role in the development of MOOCs course design (Gregory & Lokuge Dona, 2015; Lokuge Dona & Gregory, 2015a). MOOCs have successfully employed digital badges to support and encourage formative assessments as a method to engage and motivate learners to develop skills, acquire knowledge and provide feedback to others (Lokuge Dona, Gregory, & Pechenkina, 2016). There are particular challenges involved in providing large numbers of online learners with timely and meaningful feedback as they progress through a series of learning activities. However, it was evident that the use of constructivist approaches such as the five stage model explained by Salmon (2011) with e-moderating skills for e-tivities in an online environment (Salmon, 2013), enables ways to manage a large number of online learners effectively with useful and engaging feedback mechanisms (Salmon et al., 2015). Competency-badges are also proposed by Baker (2007) and are consistent with the notion of a Mini-MOOC proposed by Spector (2014b) that focuses on a tightly defined well-structured domain for which automated formative feedback can be generated.

There is much pressure in Asian countries to facilitate learning for large cohorts, especially taking distance courses. The lesson from the experience in Indonesia is that ICT needs to be integrated into formative assessment to reap better benefits. The distributed basic education project in Indonesia required thousands of in-service teachers without degrees to complete a baccalaureate or lose their jobs. In-service teachers had to do this while working. Being a full-time student while working full-time is a challenge. Those involved were constantly seeking ways to minimize such a heavy load. Getting immediate feedback on learning tasks was essential, but extremely challenging to provide. Without the support of the Internet in remote areas, the only alternative was to send tutors to the countryside to help. The lesson from the experience in Indonesia is that ICT needs to be integrated into formative assessment. The distributed basic education effort in Indonesia, funded in large part by USAID, was successful, although not all objectives were achieved. An important outcome of the effort was the impetus to make Internet access widely

available to students and teachers throughout Indonesia. Universitas Terbuka has been instrumental in realizing the goals and objective of the effort (see http://www.oeconsortium.org/members/view/568/).

Teacher support in technology-enhanced formative assessment

As is the case with nearly every change in learning and instruction, proper training and professional development in support of teachers is required. Lack of teacher support has been cited as one reason that very promising technologies have failed to scale up and achieve sustained success (Spector & Anderson, 2000). Yang et al. (2014) discussed how important it is to provide professional development to teachers to change the culture of feedback provision in classrooms and to build positive instrumental attitude towards formative assessment. In a similar vein, To and Carless (2015) also discussed the importance of providing exemplars and guiding teachers towards building strategies to implement formative feedback methods. What has not been explored is how these findings might change when formative feedback is being automatically generated by an intelligent assessment engine.

While many have discussed the need to reform teacher training and better support teacher professional development, especially in the area of technology-enhanced learning and formative assessment, there are only a few instances where this has happened on a large and sustainable scale. One example cited by OECD (Organisation for Economic Co-operation and Development) is Finland, which has steadily improved teacher training, curricula, and technologies to support learning, instruction and assessment (see https://www.oecd.org/pisa/pisaproducts/46581035.pdf). Other countries in which large-scale reforms have occurred in concert with teacher support and the integration of technologies to support learning, instruction and assessment include, among others, China, Ireland and South Korea. The fact that more progress has not occurred with regard to the adoption of advanced technologies in support of formative assessment and innovative learning environments is in part due to need to train and re-train teachers and gain societal consensus on the value and importance of committing the resources needed to support 21st century skills. We conclude the paper with some synthesizing remarks about conclusions and recommendations for future efforts.

Conclusions and recommendations

In order for the full potential of formative assessments to be realised in the context of supporting critical thinking, inquiry learning and 21st century skills, it is important for decision makers at all levels to be aware of the significance of formative assessments as well as formative evaluations (Spector & Yuen, 2016). The different institutions and technological capabilities also need to be evaluated with the professional development capabilities to implement a sound strategy for formative assessment for learning. The professional development opportunities for staff to clarify and understand the role of formative assessments and evaluations in learning and instruction should be developed, widely emphasized and disseminated. Providing relevant theoretical and empirical grounding and short but poignant examples will assist teachers and decision makers in navigating their way through the process of implementing formative assessments.

Without emphasis on formative assessment, support for new assessment tools and technologies, and an open assessments repository, it is not easy to change current formative practice and current emphasis on summative assessment and high-stakes testing. Two forms of change are required: (a) more emphasis on formative assessment (and less on summative assessment) as formative assessment is linked directly to improved learning, and (b) formative assessment practices to address learning situations that present difficult challenges (e.g., large and multi-grade classrooms, inquiry- and problem-based learning). New technologies and technology enhanced delivery modes such as MOOCs, serious games, and gamification will be unable to realize their full potential and impact on learning if new methods, tools and resources are not used effectively to encourage students to gain knowledge and learn the necessary skills. According to Shute and Ventura (2013) and Webb et al. (2013), new methods include stealth assessments (i.e., embedded and continuous unobtrusive measuring of performance while learners are engaged in computerized tasks). This type of data can be used to make meaningful interpretations about learner habits. It also can be provided to the learners, to give them a meaningful representation of evidence and arguments about their achievements. These strategies could enable a wider range of measures to contribute to judgements of students' achievements, thus supporting their learning. In addition, with the introduction of new technologies and course

delivery methods, it is also important to consider professional development of staff in order for them to be comfortable in using these models and tools.

Learning in the 21st century includes digital literacy (skills associated with searching, evaluating, using, modifying and creating digital artifacts) and reasoning literacy (critical thinking skills) among the other basic skills to be developed in primary and secondary education that need to be enhanced through formative assessment *for* learning. While technological developments have opened new methods of conducting formative assessments, it is important to analyse the suitability of such learning technologies for the purpose (Marope, Chakroun, & Holmes, 2015). Turning research tools such as HIMATT into tools usable by teachers in a variety of classrooms should be a priority for funding agencies and educational developers. Supporting learning analytics is yet another priority recommendation, although this is a challenge when much of the necessary data is held in non-open repositories. Another recommendation important with regard to personalized learner is to create accessible and robust learner profile that include preferences, interests, biases as well as performance data. Such databases have yet to be created on a large and sustainable scale but are important to fully realize the potential of personalized formative feedback. In order to move assessment into the 21st century, educational institutions need to invest in professional development and use of new tools and technologies especially well-suited for complex problem-solving domains, personalized learning and massive online learning situations. In addition, new assessment tools and technologies could be used for meaningful diagnostic and cross-cultural purposes to form the basis for informing and improving educational systems to enhance students learning. This type of supported learning environment can assist life-long learning, including developing effective problem solving and critical thinking skills.

Our basic recommendation for researchers, developers, educators and policy makes is to address the over-emphasis on summative assessments and evaluations and under-emphasis on formative assessments and evaluations. One form this could take would be in the form of an open assessment repository (OAR) or an education observatory (e.g., similar to the discontinued ERIC clearinghouses), which could be funded by governmental agencies and foundations interested in genuinely supporting 21st century skills and knowledge. A second but equally important recommendation is fund and support the development and deployment of powerful formative assessment tools that align with 21st century skills especially in the areas of critical thinking and inquiry- and problem-based learning. A final recommendation is to properly train and support teachers in the important but somewhat neglected area of formative assessment.

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