Spector, J. M. (2013). Emerging Educational Technologies and Research Directions. *Educational Technology & Society*, *16* (2), 21–30.

Emerging Educational Technologies and Research Directions

J. Michael Spector
Department of Learning Technologies, University of North Texas, USA // jmspector007@gmail.com

Abstract

Two recent publications report the emerging technologies that are likely to have a significant impact on learning and instruction: (a) New Media Consortium's *2011 Horizon Report* (Johnson, Smith, Willis, Levine & Haywood, 2011), and (b*) A Roadmap for Education Technology* funded by the National Science Foundation in the USA (to download the report see http://www.cra.org/ccc/edtech.php). Some of the common technologies mentioned in both reports include personalized learning, mobile technologies, data mining, and learning analytics. This paper analyzes and synthesizes these two reports. Two additional sources are considered in the discussion: (a) the IEEE Technical Committee on Learning Technology's report on curricula for advanced learning technology, and, (b) the European STELLAR project that is building the foundation for a network of excellence for technology enhanced learning. The analysis focuses on *enablers* of (e.g., dynamic online formative assessment for complex learning activities) and *barriers* to (e.g., accessibility and personalizability) to sustained and systemic success in improving learning and instruction with new technologies. In addition, two critical issues cutting across emerging educational technologies are identified and examined as limiting factors – namely, political and policy issues. Promising efforts by several groups (e.g., the National Technology Leadership Coalition, the IEEE Technical Committee on Learning Technology, Networks of Excellence, etc.) will be introduced as alternative ways forward. Implications for research and particular for assessment and evaluation are included in the discussion as means to establish credible criteria for improvement.

Keywords

Accessibility, Emerging technology, Network of excellence, Online assessment, Personalization

Introduction

New and more powerful information and communications technologies (ICT) continue to emerge at a rapid pace. Their use in business, government, and the entertainment sectors is widespread and the impact remarkable. E-commerce continues to grow at a rate of about 20% globally and is expected to approach a trillion US dollars in 2013 (JP Morgan, 2008). E-government is now well established at many levels in both developed and developing countries around the globe and particularly critical in times of national and international crisis (United Nations Public Administration Netwrok, 2010). The entertainment industry is perhaps the leader in ICT innovations as demonstrated by the popularity of animated 3D feature-length movies and massively multi-player games on smart phones. Given the growth and impact of ICT in other sectors, it is reasonable to wonder what impact emerging educational technologies will have on learning and instruction and how research might be directed to explore that impact.

As it happens, scholars have been exploring the issue of emerging educational technologies and their impact for years. Two recent sources will be discussed in this paper: (a) the New Media Consortium's (2011) *2011 Horizon Report* (Johnson et al, 2011), and (b) *Roadmap for Education Technology* commission by the National Science Foundation in 2010 (Woolf, 2010). In addition to these two highly regarded sources, two projects that have been exploring emerging educational technologies will also be examined and included in the discussion: (a) the European STELLAR project that is developing a network of excellence for technology enhanced learning (see http://www.stellarnet.eu/), and (b) the IEEE Technical Committee on Learning Technology's effort to recommend curricula for advanced learning technologies (Hartley, Kinshuk, Koper, Okamoto, & Spector, 2010).

The analysis will focus on enablers and barriers for systemic and sustained improvements in making effective use of ICT in learning and instruction. The paper concludes with the role that politics and policy play as enablers of and barriers to technology enhanced learning, along with recommendations for research agendas to promote technology enhanced learning.

The 2011 Horizon Report

The New Media Consortium, a globally-focused not-for-profit consortium, (see http://www.nmc.org) established the Horizon Project in 2002 to identify and describe emerging technologies that seemed likely to have a significant

impact on a variety of sectors around the world. Potential impacts on teaching, learning and creative inquiry have been a focus from the very first *Horizon Report*. The *2011 Horizon Report* (Johnson et al., 2011) includes sections on key trends, critical challenges and technologies to watch. The report identifies six technologies to watch in three time-to-adoption contexts: one year or less, two to three years, and four to five years. In addition to the primary report, there are reports on specific sectors (e.g., K-12) and regions (e.g., Australia). To gain a complete understanding of the report, it is a good idea to look at previous reports and use the new Navigator tool to explore the huge sets of data used to develop the various Horizon Reports; these are available to the general public at no cost on the NMC Website.

Key trends

The *2011 Horizon Report* identified four key trends, all of which also appeared in the *2010 Horizon Report*. First, the massive amount of resources and relationship opportunities afforded by the Internet create a continuing need to re-examine the role of an educator with regard to sense-making, coaching, and credentialing. Second, people continue to expect to work, learn and study at their convenience in terms of time and place. Third, work is increasingly collaborative which creates a need to [re-]structure student projects to reflect authentic and realistic contexts likely to be encountered outside study environments. Fourth, technologies are increasingly cloud-based. Taken together, these trends suggest that learning environments should be more collaborative and that they should make use of tools, technologies, processes and resources likely to be encountered in the workplace. While this is not ground-shaking news to educational technologists and researchers, the implications for schools really are ground-shaking in the sense that significant transformations need to occur if schools are to be responsive to such trends.

Critical challenges

Four critical challenges are also identified in the *2011 Horizon Report* (Johnson et al., 2011). First and foremost, digital media literacy is again ranked as the most important challenge. In order to maintain currency with emerging technologies and the trends previously described, being literate in the area of digital media is vital. Digital literacy is a multi-faceted skill that covers the ability to find, use, interpret, modify, and create a variety of digital media. Falling behind in this area contributes to the digital divide, which is widening just when accessibility and resources are expanding. A second significant challenge is in the area of evaluation metrics, which was noted in 2010 as well. The challenge in this area is in part because much of the research being conducted is designed for earlier forms of education resulting in no significant differences being found for new forms of education. Third, economic pressures associated with new media are challenging traditional forms of education to compete in novel ways. In response to the trend for teaching and learning anywhere and anytime, online universities and programs are attracting increasing numbers of students causing traditional universities to compete for students who would have been presumed to prefer traditional universities. Fourth, due to the proliferation of information, resources, tools and devices, it is increasingly difficult for teachers and students to maintain their knowledge and skills. As would be expected, the challenges are closely connected with the trends noted earlier. It is worth noting here that the challenge of developing appropriate evaluation metrics, along with associated assessments, is especially important in the sense that without such metrics, progress in any of the areas mentioned is merely speculative. This issue arises in the NSF Roadmap to be discussed in a subsequent section.

Technologies to watch

In the near term (one year or less), the report identifies two technologies, consistent with findings in previous years: *electronic books* and *mobile devices*. Both of these are well known and have already made their way in educational contexts. Moreover, they are consistent with the trends and challenges presented previously. Electronic books add to the wealth of information and resources available on the Internet, but they may not be accessible to everyone. Mobile devices do allow people to learning almost anywhere at their convenience, but keeping pace with new mobile devices is a challenge and there are places where the devices or the networks to facilitate their use are not accessible or affordable.

In the two-to-three year time horizon, two technologies are identified that have significant but not yet fully realized potential to impact learning and instruction: *augmented reality* and *game-based learning*. Both of these technologies are now part of mainstream popular culture in many parts of the world, but their potential to impact education is not yet fully realized. Augmented reality consists of computer generated sensory input to supplement human perception. A simple example is a mobile device used museums to assist visitors; the device might show a movie clip or play an audio file to enhance the exhibit viewer's experience. Game-based learning is not new, of course, but what is relatively new is the strength of interest in massively multiplayer games as evident at the serious games Website (see http://www.seriousgames.org/). While there is great interest in digital games and games are becoming increasingly sophisticated and popular, there is not strong evidence of improved learning on account of game-based learning experiences, although there are notable exceptions (Tobias & Fletcher, 2011). This deficiency points to the importance of the challenge for improved evaluation metrics, and for the need to connect game and education goals. While the devices to support educational gaming have become quite sophisticated, there is again the issue of access to and knowledgeable use of those devices, which in many cases detracts from the learning experience. In this author's opinion, an example of an effective educational game is one created using a validated system dynamics model that allows learners to collaboratively interact, formulate hypotheses, make decisions, and develop policies to guide future decisions (Milrad, Spector, & Davidsen, 2003).

In the four to five year time horizon, the two technologies identifies as most likely to impact learning and teaching are *gesture-based computing* and *learning analytics*. Gesture-based computing extends input from keyboard and mouse to include body and eye movements. The goal is to make interaction more intuitive and natural, although the evidence in this area is not convincing, at least not in terms of improved learning and instruction. The devices themselves are quite popular and are quite likely to continue to gain interest in entertainment contexts. The one area where gesture-based computing is likely to be directly effective is with simulators that are intended to behave like their real-world counterparts – in such cases, it is possible to make the interaction experience quite authentic and realistic, which is likely to impact learning. The other longer-term technology to watch is learning analytics. The notion of analytics is to mine very large sets of data in near-real time in order to configure an experience for a user that is likely to be relevant and of interest. Commercial e-commerce sites already do this to suggest to buyers additional purchases based on things already selected by them that matched with additional things that similarly profiled users selected. In an educational context, the notice of learning analytics can build on meaningful evaluation and assessment metrics (a challenged noted earlier) to configure particular learning experiences in a personalized learning context. For example, assume that profiles are kept on learners that include interests, preferences and previous performance. When a particular learner is struggling with a unit of instruction, the learning analytics module could search a database of similarly profiled learners who struggled with that same unit of instruction but who subsequently succeeded when given an opportunity to interact with a supporting unit of instruction. Then, the personalized learning system presents a customized learning activity based on the output of the learning analytics. Such a system is realistic and may be closer than four or five years from realization and impact in actual instructional contexts.

The NSF roadmap for education technology

In 2009, the US National Science Foundation commissioned a report on the future of educational technology. A number of meetings and workshops were convened that included leaders in several different disciplines who were tasked with making recommendations for a research agenda and future federal funding. The report from these meetings and workshops was published in 2010 (Woolf, 2010). The report focused on the role and impact of computing and technology in education, and it included research recommendations and a vision for education the year 2030. Seven grand challenges were identified followed by seven technology recommendations. In the next two sections, the grand challenges and technology recommendations are briefly characterized. The report contains a rationale for each of these challenges and recommendations, and readers are directed to the report for elaboration. In the context of this paper, the overlap with the *Horizon Report* will be emphasized, as there is a great deal of convergence, which adds credibility to both reports as they were constructed independently without overlapping authors.

Grand challenges

These grand challenges form the basis for specific research recommendations made in the *Roadmap*, some of which will be discussed in a subsequent section, and are connected with the vision for education in 2030 (that vision is not elaborated here as the emphasis here is on emerging technologies and their implications for education and research in the next few years).

- Personalizing education—a one-method fits all approach does not match up with a diverse population and the potential of new technologies; moreover, finding in cognitive psychology and new technologies make it possible to create effective learning activities to meet individual student needs and interests; this challenge fits quite well with trends and challenges cited in the *Horizon Report*.
- Assessing student learning—there is a need for effective assessments of students and teachers, not only for accountability and promotion (summative) but in order to improve learning and instruction (formative); the focus in assessment should be on improving learning, especially from a perspective of life-long learning and literacy in the information age; assessments should be seamless and ubiquitous (woven into learning activities unobtrusively); this challenge matches directly with the elaboration of evaluation metrics in the *Horizon Report*.
- Supporting social learning—supporting meaningful and collaborative learning activities is more important than ever before, partly due to requirements in the workplace to work collaboratively and partly due to the affordances of new Web 2.0 technologies; this challenge fits well with the *Horizon Report* trend pertaining to increasing collaboration and the challenges pertaining to digital media literacy and traditional models of the university.
- Diminishing boundaries—traditional boundaries between students and teachers, between and among personal abilities and types of learning, between formal and informal learning, and between learning and working are changing and becoming blurred in the 21st century; this creates a need to recognize the significance of informal learning and different learner abilities and interests; this challenge matches quite well with all of the *Horizon Report* trends and challenges.
- Developing alternative teaching strategies—the teacher is no longer the sole source of expertise in classroom settings due to the widespread availability of networked resources; this creates a need to change instructional approaches and train teachers accordingly; this challenge fits well with the challenge of new models of education and the trends cited in Horizon Report.
- Enhancing the role of stakeholders—stakeholders in education systems need to develop trust that those systems are adequately preparing students for productive lives in 21st century society; as a consequence, there is a need to regularly consult with employers, parents, administrators, teachers and students to ensure that all stakeholders have confidence that the education system is working well; this challenge matches well with the Horizon Report challenge pertaining to economic and pedagogical pressures on traditional forms of instruction.
- Addressing policy changes—the knowledge society requires flexibility on the part of an informed population; educational inequities and the digital divide can challenge the stability of a society and need to be addressed; as with the other challenges, this one matches will with several trends and challenges cited in the *Horizon Report*.

It is obvious that these challenges are interrelated, as is the case with the trends and challenges in the *Horizon Report*. It is not possible to address just one without taking into consideration the others. The *Roadmap* includes a discussion of these interrelationships along with a table that maps the grand challenges to technology features and the vision of education in 2030. Readers are referred to the *Roadmap* for additional details.

Technology recommendations

Seven information and communications technologies areas are discussed in the Roadmap that are likely to have a significant impact on learning and instruction. Each is briefly characterized so that the overlap with the *Horizon Report* can be illustrated.

- User modeling—dynamic modeling of student competencies and prior learning is an important area in which ICT can contribute to improved learning and instruction, particularly through formative assessment and personalized instruction; pursuing new methods and tools to support user modeling fits well with the *Horizon Report* trends and challenges as well as with other technology recommendations in the *Roadmap*.
- Mobile tools—new mobile devices are increasing access to and use of ever more resources to support learning activities; integrating these smart and flexible tools into education context is a priority for the future; this

recommendation matches directly with the *Horizon Report* elaboration of mobile technologies and ubiquitous access.

- Networking—access to networked resources in essential in order to maintain progress in learning and instruction in the 21st century; these resources can democratize education and help minimize the digital divide if other challenges are met; this recommendation matches directly with the Horizon Report trend pertaining to cloud-based computing.
- Serious games—the notion of fun within the context of learning has long been recognized in primary education; the role of an education game to promote motivation and interest are gaining traction in secondary and post-secondary settings; serious games are those games that have an explicit and carefully planned educational purpose; more massively parallel, multi-player online games should be pursued and designed for transfer of learning to real-world environments; this recommendation is a direct match the *Horizon Report* emphasis on game-based learning.
- Intelligent environments—the research and development of intelligent tutoring environments in the 1980s and 1990s have matured and can now be applied to many contexts with more effective student modeling to effectively support personalized learning; the recommendation is to pursue adaptive systems in a wide variety of domains consistent with the other technologies mentioned in the *Roadmap*; there is no direct match with this recommendation in the *Horizon Report* although it is consistent with nearly all of the trends and technologies elaborated in that report.
- Educational data mining—it is now possible to record, store and retrieve a great deal of education data pertaining to individual and groups of learners that can be used to provide formative assessment and personalize learning, which is the recommendation of the *Roadmap* in this area; this recommendation is a direct match with the emphasis in the *Horizon Report* on learning analytics, and links with the other technologies cited in both reports.
- Rich interfaces—rich interfaces include those technologies that can sense, recognize, analyze and react to human interaction, and these, coupled with more open-ended learning environments, can be used to promote learning and instruction in a wide variety of contexts; the recommendation is to pursue rich interfaces that are responsive to affective as well as cognitive interaction, that support augmented realities, and that can serve as personal learning companions; this recommendation matches quite well with the *Horizon Report* emphasis on gesture-based computing and augmented reality.

As was the case with the grand challenges, these technologies to watch are interrelated and should be pursued in combinations rather than as single points of emphasis in research and development agendas. Some of the specific research recommendations in the Roadmap will be elaborated in a subsequent section.

The IEEE learning technology technical committee report on curricula

The IEEE Technical Committee on Learning Technology (TCLT) established a Working Committee to develop specifications for new curricula for advanced learning technologies as a response to the demands and potential of new and emerging technologies (Hartley, Kinshuk, Koper, Okamato, & Spector 2010).The Working Committee adopted and developed a competency-based approach with regard to curricula and assessments to cover undergraduate, postgraduate and training contexts. The competences were elaborated and assembled as a framework consisting of competence domains, classes and tasks which should be useful to educators and practitioners in adopting a broader multi-disciplinary approach, and in developing greater skill and understanding when applying new technologies to improve education and training. The effort reported here represents a three-year effort that culminated in the 2010 report (Hartley et al., 2010). The reason for including a summary of this report is that it again highlights the consistency found in the Horizon Report and the Roadmap – another indication that there is broadly based convergence on a global scale of the ideas represented in those two reports. This convergence will be further emphasized in the STELLAR project to be discussed in a subsequent section of this paper.

The Working Committee agreed with Melton (1997) that developments in technology are placing growing demands on the educational system, which are necessitating changes to curricula, pedagogies and assessment procedures. Existing curricula in informatics, learning technology and instructional design are confronting serious challenges in meeting the requirements of the workplace and society in general. The effort resulted in a competency framework that included five competency domains with associated sub-domain competence classes, which are more specific competencies that provide an elaboration of each competency domain; the reader is encouraged to examine the final

report for details of competencies classes as that is beyond the scope of this paper. The five competency domains (competency clusters) are briefly characterized as a context for the thirteen advanced learning technology curricula topical areas aimed at preparing instructional technologists and educational information scientists of the 21st century.

- Knowledge competence domain—this domain includes those competences concerned with demonstrating knowledge and understanding of learning theories, of different types of advanced learning technologies (including those cited in the *Roadmap* and *Horizon Report*), technology based pedagogies, and associated research and development.
- Process competence domain—this domain focuses on skills in making effective use of tools and technologies to promote learning in the 21st century; a variety of tools ranging from those which support virtual learning environments to those with pertain to simulation and gaming are mentioned.
- Application process domain—this domain concerns the application of advanced learning technologies in practice and actual educational settings, including the full range of life-cycle issues from analysis and planning to implementation and evaluation.
- Personal and social competence domain—consistent with the emphases cited in the *Roadmap* and *Horizon Report*, the report emphasize the need to support and develop social and collaboration skills while developing autonomous and independent learning skills vital to lifelong learning in the information age.
- Innovative and creative competence domain—this domain specifically recognizes that technologies will continue to change and that there is a need to be flexible and creative in making effective use of new technologies; becoming effective change agents within the education system is an important competence domain for instructional technologists and information scientists; this competency cluster is especially consistent with the *Horizon Report* challenge pertaining to the changing nature of education systems and the emphasis in the *Roadmap* on enhancing the role of stakeholders and addressing policy changes.

The Working Committee report (Hartley et al., 2010) identified thirteen topical areas that might be included in curricula in the future, each of which is elaborated in more detail in the report. The purpose here is simply to suggest a convergence of emphasis in the various reports pertaining to emerging technologies and the implications for learning, teacher preparation and research. The topical areas include the following:

- Introduction to advanced learning technologies—an historical overview of the evolution of learning technologies to provide a grounding in lessons learned from past efforts.
- Introduction to human learning in relation to new technologies—an elaboration of the contributions of cognitive psychologists and instructional designers in recent years.
- Foundations, evolution and developments in advanced learning technologies—emphasis on the affordances of new technologies, especially those pertaining to social networking, mobile devices and adaptive technologies (all of which are mentioned in the *Horizon Report* and the *Roadmap*).
- Typologies and key approaches to advanced learning technologies—elaboration of the links between and among taxonomies of technologies, technologies affordances, pedagogical approaches, and learning goals and objectives.
- User perspectives of advanced learning technologies—detailed treatment of the roles, expectations, and responsibilities of the various users involved with education systems involving new and emerging technologies.
- Learner perspectives of advanced learning technologies—elaboration of how various learners view and use new and emerging technologies for a variety of purposes.
- System perspectives of advanced learning technologies—emphasis on a systems level understand of new technologies and a holistic view of how effective technology integration can and does take place.
- Social perspectives of advanced learning technologies—emphasis on collaborative work, multi-disciplinary groups, and organizational and management issues involved in making effective use of new technologies.
- Design requirements—development of competence in the area of identifying critical design issues and creating effective plans to meet the challenges of user modeling, adaptive systems, and access to networked resources (again these are all technologies identified in the *Horizon Report* and the *Roadmap*).
- Design processes and development lifecycles—development of competence in such areas as needs assessment, requirements analysis, interface design, and authoring tools.
- Instructional design and the learning objects approach—up-to-date treatment of instructional design with emphasis on creating and using learning objects and flexible packaging of reusable and open-source components.
- Evaluation models and perspectives—emphasis on the need to construct and conduct comprehensive formative and summative evaluations in order to systematically improve learning and instructional systems; this topical

area is particularly well matched the emphasis in the *Horizon Report* on evaluation metrics the emphasis in the *Roadmap* on assessments.

- Emerging issues in advanced learning technologies—explicit recognition that technologies change and new ones will emerge, creating new challenges and an ongoing need to be flexible and creative in making effective use of learning technologies.

While these thirteen topical areas are generally well matched with the trends, challenges and technologies discussed in the *Horizon Report* and the *Roadmap*, they are particularly pertinent in emphasizing the need to properly prepare the teachers, instructional designers and information scientists of the future. It is clear that powerful educational technologies exist and will continue to emerge. What is not clear is how well we will be able to make effective use of those technologies. Without proper training of teachers and others, it is likely that new technologies will suffer the fate of so many educational technologies of the past – little impact on learning and marginal adoption rates. We can and should do better with these powerful new technologies, and serious and seriously changed curricula are required in order to do so.

A network of excellence for technology enhanced learning

A fourth source to emphasize the convergence of thinking about emerging educational technologies is the STELLAR Project that is developing a network of excellence in the area of technology enhanced learning (see http://www.stellarnet.eu). This three-year European project that will end in 2012 has already developed a number of resources that are available to the general public. In addition, networks to support advanced graduate students and connect TEL (Technology Enhanced Learning) scholars and researchers around the world are in place. The STELLAR Project identified five grand challenges (see http://www.stellarnet.eu):

- Provide a unifying framework for research;
- Engage the TEL community in scientific debate and discussion to develop awareness of and respect for different theoretical and methodological perspectives;
- Build TEL knowledge;
- Developing an understanding of how Web 2.0 technologies can support the construction of knowledge and research; and,
- Develop strategies for TEL instruments to feed and fuel ongoing developments.

The elaboration of these challenges is quite consistent with those discussed in the *Horizon Report* and the *Roadmap*, although the language used to express the challenges is somewhat different. Again we find emphasis on technologies (e.g., Web 2.0 technologies) mentioned in the other reports. The third and fourth challenges mentioned above are completely consistent with the Working Committee report on curricula for advanced learning technologies. The convergence with the previous reports discussed is even more obvious when three STELLAR guiding themes are considered:

- Connecting learning through networked learning and learner networks; this brings to mind the *Horizon Report* emphasis on cloud-based computing, the *Roadmap* emphasis on supporting social learning and the Working Committee report with its personal and social competence domain.
- Orchestrating learning with an emphasis on the role of teachers, the importance of meaningful assessments, and a focus on higher order knowledge and skills; this them is directly aligned with the *Horizon Report*'s discussion of the changing roles of educators, evaluation metrics, and new education systems, the *Roadmap*'s discussion of personalized education, assessing student learning, and alternative teaching methods, and the Working Committee's curricula recommendations in many competence areas.
- Contextualizing virtual learning environments and instrumentalizing learning contexts with an emphasis on novel experiences, new technologies, the mobility of learners and standards for interoperability; this theme aligns well with the emphasis in the other reports on augmented reality, alternative teaching methods, evaluation metrics, learning analytics, mobile technologies, and so on.

In summary, the convergence in these four sources of thinking about new and emerging technologies and their potential impact on learning and instruction is quite remarkable. The trends, challenges, and technologies discussed in these four sources are not all that new. They might be summarized as follows: (a) there will be smaller, more portable and more flexible devices to support learning; (b) there will be larger and more powerful information and

learning repositories to use in constructing learning experiences, assessing learning, and supporting personalized instruction; (c) educational environments will continued to become richer in terms of interaction, collaboration, media modalities, connectivity, collaboration, assessment; (d) learning activities will become increasing focused on problem solving and critical reasoning skills in authentic contexts; and (e) more holistic approaches (e.g., collaborative learning, emphasis on both affective and cognitive aspects of learning, etc.) to learning and instruction will displace traditional atomistic approaches that focus on individual learners and simpler learning tasks (e.g., declarative knowledge and simple, decontextualized procedures (Spector, 2000; Spector & Anderson, 2000).

Given such convergence among the academic community, one wonders if the recommendations and visions will materialize. What might stand in the say of realizing the potential of new and emerging technologies? What are the likely enablers and barriers?

Enablers and barriers

Enablers of successful integration of new technologies to improve learning and instruction are easily linked with barriers to success, and they fall mainly into two categories: (a) technology and infrastructure, and (b) human use and adoption. There is no shortage of powerful new technologies and many are quite affordable. For the technologies discussed in this paper to have an impact, access and supporting infrastructure are critical factors. Widespread, affordable and unfettered access to the Internet is basic. Without access to what the *Horizon Report* called *cloud-computing* and other reports simply referred to as the Web, very little progress or change is possible. Internet access and the supporting infrastructure are essential enablers of ongoing progress. Lack of such access becomes a barrier to progress and will serve to widen the digital divide. Simply stated, the technology and infrastructure barriers can be overcome with a modest investment of resources, and they must be overcome in order to ensure progress in the area of technology enhanced learning.

The issue of human use and adoption of new technologies is much more complex and challenging, as noted in several reports. Humans, both individuals and groups, are not always rational. Being rational involves being able to (a) articulate clearly stated goals, (b) identify and assess alternative means of achieving those goals, (c) follow-through with consistent and determined action consistent with the goals, and (d) evaluate progress and make appropriate adjustments. Such rationality requires a willingness to examine evidence, especially evidence that may be counter-intuitive or not well-aligned with one's predispositions. Consistent with many examples of concerted human behavior in many different domains, it is perhaps reasonable to conclude that humans are only intermittently rational. Some will resist integrating new technologies as doing so may seem to threaten practices that have become comfortable routines. Others may resist new technologies as they worry that students will be more adept with those technologies than they are. Still others may simply believe that what worked for them and famously successful people of their generation should be good enough for anyone. Other patterns of resistance to change and the adoption of new technologies can be cited as well. The Working Committee report emphasized the need for educational technologists and information scientists of the future to become effective advocates of change. This is a skill that is not easily or readily acquired, and in addition to the difficulty of developing skills of change agency, there is a need to be recognized as a legitimate source of expertise. Again this emphasizes the need to properly prepare people to function in an atmosphere of rapidly changing technologies with resistant populations and limited budgets. There are a few cases where human use and adoption issues have been addressed at a national level with remarkable success (e.g., Ireland, Japan, and South Korea). The larger and more diverse the society involved is, the more serious are the challenges posed by human use and adoption. Still, this area should be addressed, as suggested by all four sources discussed above.

On the human side of barriers and enablers, politics and policies stand out as perhaps the greatest challenge. Policies are developed and implemented at multiple levels, ranging from the school and district level, to the state, regional and national level. When policies are viewed as constraining and restrictive by teachers and learners, it is not likely that progress will occur, in spite of adequate technology and infrastructure. This is the case in many places in the USA where state-mandated testing in accordance with the national No Child Left Behind (NCLB) law is viewed as interfering with ongoing learning activities. In many schools in the USA, learning is interrupted for a week or longer devoted to preparing for and taking the mandated tests. Moreover, those tests seldom serve the constructive purpose of improving learning and instruction or encouraging specific educational practices. Rather, they are viewed as punishing poorly students, teachers and schools. If this personal assessment of NCLB is at all accurate, then the

conclusion is that this is a case of a policy serving as a barrier to progress even though it was intended to be an enabler.

Research directions

The *Roadmap* addresses research directions throughout the report with too many recommendations to discuss in this short paper. Because assessment is an area cited by all of the sources as a critical factor in improving learning and instruction with technologies, the focus here is on research in the area of assessment. The *Roadmap* and the IEEE Working Committee both cite competencies as a focal point for assessment. This is a traditional view of assessment – namely that assessments should be aligned with objectives. However, all of the sources emphasize formative assessments. The *Roadmap* discusses the importance of assessments that are useful to all parties. From a learner's perspective, this amount to a formative assessment that identifies a particularly difficult area along with recommended activities and resources that might help improve progress (Shute, 2008). In addition, formative assessments that are dynamic and occur in the context of specific learning activities are quite useful. As a consequence, the *Roadmap* encourages research aimed at developing dynamic, formative assessments, especially for learning activities that involve complex learning tasks.

Two specific advanced assessment technologies are worth mentioning that are specifically aimed at supporting the goals and visions of learning with advanced technologies discussed in this paper. The first of these involves using an annotated and dynamic concept map technology developed by Pirnay-Dummer, Ifenthaler, and Spector (2010). The general notion is that when a learner is confronted with a challenging, ill-structured problem (e.g., engineering design, environmental planning, technology integration), it is possible to elicit how the learner is conceptualizing the problem space, compare that representation with how highly experienced persons have conceptualized the same problem space, dynamically analyze similarities and differences, and use that analysis to encourage the learner to consider alternative solution approaches or perhaps to focus on a previously overlooked aspect of the problem.

The second technology is to make use of stealth assessments—that is to say, collect data on student performance in the course of a student or group of students working online on a problem solving activity. Such data may be log data from a computer system, for example. An analysis can be conducted on such files to determine what was done or not done. The stealth assessment system might then prompt the student to consider an alternative course of action or explore some part of the system previously ignored based on the analysis of the log file.

Both stealth assessment and dynamic concept map assessment have been demonstrated to be effective in a variety of learning situations. Both technologies exist but require funding support to become mainstream educational assessment tools available at low cost for widespread use throughout an education system. In addition, there are many important research questions worth investigating with regard to both of these representative emerging assessment technologies, including when it makes sense to interrupt the learner given a variety of situations, how learning advice is most effectively offered (e.g., suggestive vs. directive), and why learners follow or fail to follow advice offered by such assessment agents.

Conclusion

Four highly reputable sources of views and perspectives on new and emerging educational technologies have been reviewed and discussed. What is evident from this review and the discussion is that powerful technologies continue to emerge that can have significant impact on learning and instruction. What is not clear is to what extent the recommendations for research and the visions for education will be realized. Significant barriers remain, including budgetary matters, social perspectives that do not always place high value on education, and natural human tendencies to resist change. We have the means and wherewithal to transform learning and instruction and to make education affordable and accessible for nearly everyone on this planet. Will that happen? If one judges the future based on the past, the conclusion is that such transformations are not likely to happen on a global basis, although they will surely occur on a limited and local basis. It is perhaps unwise to place faith in educational progress in the technologies alone, regardless of how powerful and promising they are. Perhaps we ought to place our faith in properly trained, persistent, and dedicated teachers, designers, administrators, policy makers and parents—that is this author's conclusion.

Acknowledgements

This paper is based on an invited presentation at the 6th International Conference on e-Learning and Games, Edutainment 2011, held in Taipei, Taiwan 7-9 September 2011.

References

Hartley, R., Kinshuk, Koper, R., Okamoto, T., & Spector, J. M. (2010). The education and training of learning technologists: A competences approach. *Educational Technology & Society, 13*(2), 206-216.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 horizon report.* Austin, Texas: The New Media Consortium.

JP Morgan. (2008). *Nothing but net: 2008 Internet investment guide.* Retrieved on 20 November 2011 from https://mm.jpmorgan.com/stp/t/c.do?i=2082C248&u=a_p*d_170762.pdf*h_-3ohpnmv

Melton, R. (1997). *Objectives, competences and learning outcomes: Developing instructional materials in open and distance learning*. London, UK: Kogan Page.

Milrad, M., Spector, J. M., & Davidsen, P. I. (2003). Model facilitated learning. In S. Naidu (Ed.), *Learning and teaching with technology: Principles and practices* (pp. 13-27). London, UK: Kogan Page.

Pirnay-Dummer, P., Ifenthaler, D., & Spector, J. M. (2010). Highly integrated model assessment technology and tools. *Educational Technology Research & Development, 58*(1), 3-18.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153-189.

Spector, J. M. (2000). Towards a philosophy of instruction. *Educational Technology & Society, 3*(3), 522-525.

Spector, J. M., & Anderson, T. M. (Eds.) (2000). *Integrated and holistic perspectives on learning, instruction and technology: Understanding complexity.* Dordrecht, Netherland: Kluwer Academic Press.

Tobias, S., & Fletcher, J. D. (Eds.) (2011). *Computer games and instruction*. Charlotte, NC: Information Age Publishing.

United Nations Public Administration Netwrok (2010). *Leveraging e-government at a time of financial and economic crisis*. Retrieved on 20 November 2011 from http://unpan1.un.org/intradoc/groups/public/documents/un/unpan038851.pdf

Woolf, B. P. (Ed.) (2010). *A roadmap for education technology*. Washington, DC: National Science Foundation. Retrieved on 20 November from http://www.cra.org/ccc/docs/groe/Roadmap%20for%20Education%20Technology%20-%20Summary%20Brochure.pdf