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Emerging educational technologies: Tensions and synergy

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Abstract A review of high level sources with regard to new and emerging technologies was conducted. Three technologies, according to these sources, appear especially promising: (a) massive open online courses (MOOCs), (b) personalized learning, and (c) game-based learning. This paper will review information from the US National Science Foundation, the US Department of Education, the New Media Consortium, and two European Networks of Excellence with regard to new and emerging technologies. A critique will then be provided using established principles pertaining to learning and instruction and a recommended curriculum for advanced learning technologies. The general result is that it appears that some educational technology advocates are overstating the likelihood of these three technologies having a significant and sustained impact in the near future, although there are promising aspects to each of these technologies in the long term.

1. Introduction

It is obviously true that technology changes and that changes are happening at an ever increasing pace with regard to digital technologies. This rapid pace of change places a burden on educators and instructional designers. The challenge is to make effective use of new technologies while preparing students for productive lives in the 21st century. Three technologies will be examined in this paper with regard to their likely impact on learning and instruction: (a) massive open online courses (MOOCs), (b) personalized learning, and (c) game-based learning. The sources that will be examined that propose these as promising technologies include a report entitled "Roadmap for Education Technology commissioned by the National Science Foundation" (Woolf, 2010), the US National Educational Plan (REF), the European Network of Excellence for Technology Enhanced Learning (STELLAR; REF), the European Network of Excellence for Game-based Learning (GaLA; REF), and the New Media Consortium's 2013 Horizon Report for Higher Education (REF). A critical review will be provided that shows that there are serious challenges for each of these promising new technologies. The conclusion will suggest what needs to be done in order for these technologies to have the impact their proponents envision.

As a foundation for what follows, several definitions and principles are necessary to consider. First, it is necessary to say how education should be considered. Education involves the systematic development of knowledge, skills, and attitudes that are likely to prepare individuals and groups of individuals to be responsible, thoughtful and productive members of society (Dewey, 1910, 1938). Each part of this definition is essential. Education clearly involves learning (knowledge, skills and attitudes). Developing responsible individuals involves the application of knowledge, skills and attitudes to the benefit of many without disadvantaging any particular individual or group (responsibility). Thoughtfulness is of vital

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importance to a stable and sustainable society; having citizens who are critical thinkers and who can actively contribute to the future is essential in an open society. Having a population of productive workers who can and do contribute to the general wellbeing of society is also important. These are the critical attributes that most societies value in an education system, although they have yet to be universally or uniformly embraced in many education systems.

Of obvious relevance to education is the concept of learning. Simply stated, learning is characterized by stable and persistent changes in what a person or group of people know and can do (Spector, 2012). A key attribute of learning is change – learning is aimed at changing what people know and can do. This attribute leads to an assessment principle – namely, assessing learning is fundamentally about determining that desirable changes have occurred and are likely to persist. Instruction is that which is intended to facilitate and support learning. Technology can be defined as the systematic application of knowledge for a purpose – typically a purpose that is aimed to benefit a group of individuals. While these definitions are commonly and widely accepted, they are often overlooked when discussing educational technology and learning in the 21st century.

Based on these definitions, one can generally describe three kinds of digital objects often involved in learning and instruction. First, there are knowledge objects. A knowledge object is primarily an information resource, often available in a digital form through the Internet. Many such knowledge objects can be found on the Internet, and the number and variety of such objects is increasing quite rapidly. Obvious examples include the information found in Wikipedia and other Internet encyclopedias and knowledge repositories are widely available and frequently accessed on the Internet. While we have at our fingertips a wealth of knowledge objects, they do not constitute learning or instruction. A learning object can be defined as a knowledge object linked to a particular learning goal or objective. There are fewer such learning objects available on the Internet compared with the wealth of knowledge objects readily available. Teachers often provide a learning objective to help students find relevant knowledge to support learning. Still, learning objects lack essential attributes of instruction – namely, active support for learning (developing desired changes) and a way to determine that desired changes have occurred (assessment). An instructional object can then be defined as a learning object with support for learning and assessment added.

As the three promising technologies are discussed in what follows, the extent to which each of those technologies has the attributes of knowledge, learning and instructional objects will be indicated. In addition, there are well established principles of learning that should be taken into account. Of particular relevance are the following principles: (a) timely, informative feedback is an essential aspect of instruction; (b) time-on-task is an essential aspect of mastering learning tasks; and, (c) prior knowledge and understanding is essential for mastering many new learning tasks. Each of these principles needs to be applied in a manner that takes into account individual differences. Advanced learners require less feedback than learners new to a learning domain. Motivating individuals to spend more time on a learning task varies a great deal with individuals who have different beliefs and attitudes. Providing meaningful examples and non-examples also varies for individuals with different backgrounds and preparation. It is not reasonable to assume that all students are equally well-prepared and bring all of the relevant background and interest to a particular subject or learning task.

Finally, it is worth noting that learning is a naturally occurring human activity. People naturally and continually create internal representations of the things they experience in life and in a learning experience in order to make sense of those experiences. These internal representations can facilitate or inhibit learning. A particular challenge for teachers is to determine what these internal representations are like and how they may be helping or hindering learning. This is a challenge since those internal representations are not easily accessible and only indirectly observable. Fortunately, humans have a second naturally occurring capability – namely, language. People talk about their internal representations, and sometimes they create other artifacts that reflect those representations. As a consequence, this discussion assumes a socio-constructivist epistemological perspective (Spector, 2012) with regard to the critique of educational technology.

2. Materials and methods

2.1. A roadmap for education technology

The 2010 NSF *Roadmap for Education Technology* (Woolf, 2010) cites eight grand challenges for education technology (http://www.cra.org/ccc/files/docs/groe/GROE%20Roadmap%20for%20Education%20Technology%20Final%20Report.pdf):

- Personalizing education (customizing learning and instruction to match individual interests, knowledge, skills, attitudes, and interests),
- Assessing student learning (providing formative feedback during instruction as well as summative assessment after instruction that is clearly linked to desired outcomes),
- Supporting social learning (engaging groups of learners in meaningful activities as this will be expected in many work environments and is likely to promote learning complex tasks),
- Diminishing boundaries (making instruction more accessible to workers, parents, and others outside a traditional school-based environment),
- Alternative teaching methods (as learners gain competence and confidence, providing more open-ended exploratory activities likely to result in deeper insight),
- Enhancing the role of stakeholders (engaging decision makers at multiple levels to ensure that learning and instruction are adequately supported),
- Life-long learning approaches (active recognition and support for learning that continues beyond the boundaries of formal learning programs), and
- Addressing policy changes (promoting evidence-based policies at a high level so that promising new technologies are not used simply as replacements for existing tools and methods but as tools to reform and promote deep understanding).

Formative feedback is feedback provided to the learners during instruction aimed at improving knowledge, skills, and attitudes and/or correcting misunderstandings or wrongheaded approaches to solving problems. The significance of formative feedback will be discussed later in this paper. When the emphasis is on improving understanding and learner performance, formative feedback is the kind of assessment that is most likely to have significant results.

The Roadmap then indicates the following technology capabilities at supporting these challenges for the next twenty years: (a) mobile systems, (b) intelligent environments, (c) remote access to information, (d) student modeling, (e) open-learning models, (f) choice-adaptive systems, (g) data management tools, (h) rich interfaces, (i) multi-modal communications), (j) social networks, and (k) intelligent search engines. These technologies will reappear in the other sources to be cited next. Only personalized learning appears as one of the three chosen herein as a focus, but the capabilities just listed are very congruent with MOOCs and game-based learning, which are mentioned in the body of the report several times with particular emphasis on serious games.

2.2. The US education technology plan

The National Education Technology Plan, *Transforming American Education: Learning Powered by Technology* (*see* http://www.ed.gov/technology/netp-2010), represents a national call to apply advanced technologies used in business and everyday life in education to improve learning, accelerate the diffusion of effective practices, and use data to guide continuous improvement. The plan presents five essential components of learning enhanced by technology: Learning, Assessment, Teaching, Infrastructure, and Productivity. In summary form, this plan calls for (a) cost-effective strategies to improve learning outcomes and graduation rates, (b) embracing innovation, prompt implementation, and continuous improvement, (c) leveraging technology to provide engaging and powerful learning experiences. While this plan does explicitly mention any of the three technologies of focus in this paper, it does advocate the same kinds of general things found in the other reports. Moreover, it has been used as a basis to justify personalized learning and learning analytics on many occasions and as a basis for support of MOOCs and game-based learning less directly.

2.3. The New Media Consortium's Horizon Report

The New Media Consortium's 2013 Horizon Report Higher Education Edition (see http://www.nmc.org/pdf/2013-horizon-report-HE.pdf) is a continuation of annual reports on promising new technologies for education that are tracked and analyzed by the international consortium. Each year, trends are presented along with new technologies likely to have a short-, medium- and long-term impact on learning and instruction. This year's report cites the following trends:

- Openness: open content, open data, open resources, easy access to data, transparency,
- MOOCs as alternatives to traditional university courses,
- Workforce demands for more informal learning experiences,
- New sources of data for personalizing learning and for meaningful performance measurements,
- Changing the role of educators due to vast resources available via the Internet, and
- Changing education paradigms (more online/hybrid/collaborative efforts).

These trends are quite consistent with the previous two reports. Both MOOCs and personalized learning are specifically mentioned as representing trends. The specific technologies discussed in the 2013 Horizon Report are as follows:

- Near-term: MOOCS and tablet computing;
- Mid-term: Games and gamification, and learning analytics;
- Far-term: 3D printing and wearable technologies (e.g., Google glass).

Some of the categorization can of course be questioned. For example, 3D printing now widely used in both higher education and many K-12 settings is already a mature and affordable technology. MOOCs are certainly receiving a great deal of public attention and in a sense may be a near-term technology, but there are important missing aspects of MOOCs which suggest that this is not yet a mature technology. In any case, this report brings together the trends and technologies mentioned in the previous reports and emphasizes the three technologies of focus in the discussion below.

2.4. The European Network of Excellence for Technology Enhanced Learning (STELLAR)

The European Network of Excellence for Technology Enhanced Learning (STELLAR; see http://www.stellarnet.eu/ and also http://www.teleurope.eu/pg/frontpage) represented a continuation of prior European efforts to build networks of excellence to promote learning and instruction in the European Community. STELLAR was predicated on the view that in today's knowledge society, people are faced with new challenges and career transitions (e.g., between companies, between formal institutional learning and informal learning, between learning for personal growth as well as for work). STELLAR addressed several existing problems: (a) significant fragmentation with regard to the use and development of advanced learning technologies, (b) disjoint scientific and educational research communities, and (c) a fragmentation of disciplines. These same problems exist outside Europe, and the works of this network are still available and ongoing through the two sites indicated above.

Consistent with the problems cited, STELLAR identified a number of grand challenges:

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

- To address these challenges, which have counterparts in the previous reports, STELLAR adopted the following guiding themes:
- Connecting learners – networked learning and learner networks;
- Orchestrating learning – roles of teachers, role of assessment, higher order knowledge and skills; and
- Contextualizing virtual learning environments and instrumentalizing learning contexts – novel experiences and new technologies, mobility of learners, as well as standards for interoperability.

The work conducted in support of these themes includes significant efforts in support of social network analysis and standard definitions and instruments to measure progress (see the two sites indicated previously). Personalizing learning is one thread that permeates much of the Network's efforts. In addition, there is emphasis on using data analytics to support learning and instruction, which will appear again in the critique of the three focus technologies.

2.5. The European Network of Excellence for Game-based Learning (GaLA)

The European Network of Excellence for Game-based Learning (GaLA – Game and Learning Alliance; see http://www.galanoe.eu/) is an ongoing project to promote the effective use of games in learning and instruction with a focus on bringing those working in the field of electronic games with those working in the area of technology-enhanced learning. As with the STELLAR project, all of the findings and reports of the project are freely available to anyone on the site indicated above. The GaLA project has already formed a new European-centric society for serious games and a new journal to promote game-based learning.

The GaLA project began with an awareness of the history of the successful use of games to support early learning (simple tasks – easy to align game goal with learning goal), especially in K-12 public school settings. In fact, games have a long history of use and success in primary school education. With the advent of digital technologies, the use of games in primary schooling has expanded significantly. Moreover, advocates of game-based learning argue, with some evidence, that the motivational aspects of games attract some who might not be interested in a topic to become more interested and engaged. As stated previously, the time a student spends on a learning task and with a set of learning problems is correlated with learning outcomes. In addition, there is recent interest in using games to support adult learning – even in complex and ill-structured problem solving domains as well as in the area of soft skills (e.g., leadership training). The GaLA project is primarily focused on developing evidence that games can be used effectively to support learning in higher education as well as in settings in business and governmental and non-governmental agencies. The evidence for success in this area is not yet convincing, however.

2.6. The IEEE technical committee on learning technology curriculum report

The changes in educational technology reported above have implications not only for their use in education but also in training educational technologists. The IEEE technical committee on learning technology established a working committee to develop specifications for new curricula for advanced learning technologies. The working committee's 2010 report (Hartley et al., 2010) reported the results of a three-year effort to explore what various constituencies (academics and industry leaders, primarily) believed relevant to prepare educational technologists in the 21st century. The committee adopted a competency-based approached and clustered findings into the follow topical areas:

- Introduction to Advanced Learning Technologies (ALT);
- Introduction to Human Learning in Relation to ALT;
- Foundations, Developments and Evolution;
- User Perspectives;
- Learner Perspectives;
- Systems Perspectives;
- Social Perspectives;
- Design Requirements;
- Instructional Design;
- Evaluation Models and Practices; and
- Emerging issues.

For each of these areas, there were associated sets of knowledge, skills, and attitudes that were clustered into these competency areas: (a) knowledge competence (basic facts, concepts, and principles) (b) process competence (procedural knowledge with regard to analysis, planning, implementation, deployment, and evaluation activities), (c) application competence (the ability to create meaningful components of advanced learning environments, (d) personal and social competence (the ability to work with others since the domain requires teamwork and group activities at nearly every level), and (e) innovation and creativity competence (important since technologies change and the ability to effectively integrate new technologies or to work with new contexts requires innovation and creativity).

This curriculum structure has yet to be realized, but it is mentioned here as it highlights some of the critical factors that are likely to influence the success of the three focus technologies. Moreover, this report highlights the general trends cited in the reports discussed previously. Specifically, there is a general trend toward more holistic approaches in the use of learning technologies, and this has implications for how educational technologists are trained. A holistic approach recognizes that learning often involves interdisciplinary groups working together as well as both formal and informal learning experiences. Training educational technologists in these areas as well as more familiar areas is important if there is any expectation for the sustained success of new technologies. The deficiency in this area of preparing teachers, trainers, and educational technologists is in fact the first critique of the three focus technologies. In none of the three areas (MOOCs, personalized learning, and game-based learning) have issues pertaining to the systematic training of instructional designers and instructors been addressed on any significant scale.

3. Results

The immediate outcome of reviewing these sources for promising educational technologies is that there is a high degree of agreement with regard to specific technologies as well as to what the challenges are confronting successful implementation of those technologies on any significant scale. The three technologies focused on herein (MOOCs, personalized learning, and game-based learning) appear either directly or indirectly in all of these, sources. Moreover, the popular literature in the area of educational technology reflect similar consensus that these are in fact promising new technologies. In addition, the challenges and issues cited in these reports are remarkably consistent. Namely, these outcomes thread throughout the report:

- policy makers and decision makers need to be involved;
- collaborative learning is important in both formal and informal contexts;
- motivational issues are important to consider in nearly every context;
- personalizing learning experiences will make learning more meaningful and effective;
- mobile technologies are here to stay and should be used more;
- rich repositories of information are also here to stay and should be utilized;
- assessing authentic learning through performance as well as knowledge assessments;
- an emphasis on formative feedback;
- games to promote motivation and interaction;
- developing critical thinking skills and conceptual development beyond simple mastery;
- user modeling to support personalized learning;
- open access and open learning;
- data mining, learning analytics and evidence-based planning and development; and,
- gaining and maintaining stakeholder interests in technology-enhanced learning.

What is missing is a critical review of specific technologies and what they lack in order to have the impact imagined. The section presents a critical review of three focal technologies.

4. Discussion

4.1. MOOCs

Massive, open online courses (MOOCs) appear to provide unique opportunities to anyone to gain education and training in a variety of areas. A MOOC is freely and openly available to anyone with an Internet connection. Examples include the Khan Academy (see https://www.khanacademy.org/), Udemy (see https://www.udemy.com/), Peer-to-Peer University (see https://p2pu.org/en/), Udacity (see https://www.udacity.com), and Coursera (see https://www.coursera.org/), among others. The fundamental argument in favor of MOOCs is that anyone can learn anything, anywhere, at any time.

In *Making Sense of MOOCS* (2012), Sir John Daniel notes that early MOOCs were based on connectivism and networking within a more open-ended environment whereas more recent MOOCs have been based on a more behaviorist approach with specific learning objectives and tasks. However, MOOCs have a pattern of attracting very large numbers of participants (e.g., 155,000 for an MIT MOOC) with a very high attrition rate (e.g., 95%). A 5% pass rate for a typical university course would be considered unacceptable. Why should that be acceptable for a MOOC? Why is the attrition rate so high for most MOOCs?

Many of the existing MOOCs have not been designed by professional instructional designers and undergone rigorous formative evaluation and testing. Rather, the typical MOOC is based on an existing university course taught by a highly regarded and widely known academic. Fame and charisma may not be the crucial components in the design of an effective course.

A more serious deficiency is that MOOCs are basically a collection of knowledge and learning objects that may or may not cohere in a meaningful way. A typical MOOC cannot be considered a collection of instructional objects as critical components are missing – namely, learning guidance and formative feedback to learners during instruction and a competency based assessment at the end of instruction. It is possible for a MOOC built around declarative knowledge and simple procedures to include these missing components, but even in those highly restricted cases, the missing components are typically only provided to the very small number of students who are paying and who will be given a grade.

Until or unless MOOCs provide continuing support, formative feedback and summative feedback for open access students, MOOCs should not in fact be considered courses. These capabilities are in fact within reach of a MOOC as learning analytics and dynamic online assessment technologies mature. As a consequence, MOOCs should be considered far-term or not yet mature technologies. It is worth noting, however, that some MOOCs are being used by teachers to supplement their existing courses and those teachers are providing some or all of the missing components. This practice should be encouraged whenever circumstances allow.

4.2. Personalized learning

The concept of personalizing learning has been around for a long time. There is the well known paper by Bloom (1984) on individual tutoring in which individualized one-to-one tutoring resulted in a two standard deviation improvement in learning in several subject areas. Part of the effect was a result of increased and focused time on task but part was also due to the ability of a human tutor to adjust the instruction to fit the individual learner. Ever since, educational technologists have been trying to find ways to gain a similar effect through technology since not every student can have a personal tutor. The intelligent tutoring systems (ITSs) movement in the 1980s represented a concerted effort to accomplish this. However, the successes of ITSs were limited to very well-structured learning domains in which the common problems and misconceptions were well known so that when a particular student made a recognizable error, the instruction was automatically adjusted to address particular student's individual and specific misunderstanding or problem. ITSs had a pre-construction representation of the knowledge to be learned, pre-constructed libraries of common errors as well as a pre-constructed inference engine that indicated where in the instructional knowledge domain to focus when a particular problem was encountered. Learners were being modeled but in a very limited manner, often restricted to what they had already learned and which problem they were encountering.

Modern personalized learning is being promoted in a manner analogous to how Internet-based enterprises are modeling consumers and then recommending additional things to purchase. A commercial recommendation engine is storing information on consumers with regard to their demographics (whatever is legally obtainable, which is a great deal), inferred interests, as well as their specific purchases. When someone shows interest in or purchases a specific item, the recommendation engine then consults the huge repository of consumer analytics to see what other consumers with similar demographics and interests in fact purchased and then recommends those items to the online consumer in real time. The notion in personalized learning is that similar information can be collected on learners, including basic demographic information, things already learned, interests, current learning activities and assignments. When a learner struggles with a particular task, the recommendation engine can then consult its learning analytics repository to see what worked with other learners similarly situated. In addition, when a learner succeeds with a particular task, the recommendation engine can then consult that learner's profile and see what new learning tasks and objective are coming up and configure a unit of instruction tailored to that individual's interests, prior knowledge, learning style, and other preferences.

That kind of personalized learning technology is clearly possible. However, it has yet to be implemented anywhere on any significant scale. What is missing are the learning analytics necessary to support such a system, and the support of educational institutions to make such a radical change in how instruction is organized and orchestrated for learners. As a consequence, while personalized learning appears highly desirable, it cannot be considered a mature technology.

4.3. Game-based learning

As mentioned previously, games have long been used in primary education to teach simple concepts and procedures. Digital games are now being used at every level of education for both simple and more challenging learning tasks. However, research suggests that while games can indeed be used to motivate and generate interest, it is quite difficult to show that learning improves significantly on account of a game-based learning experience (Tobias and Fletcher, 2007). There exists extensive research to show that simulation-based learning can be highly effective, the research on games is not nearly as convincing (Spector, 2000). The difference is that simulation-based learning is typically tightly linked to specific learning objectives and progress toward those objectives are more easily measured within the simulation environment itself. However, it is quite challenging to align the game goal with a learning goal when the subject matter is complex, as is the case for most cases in higher education. In addition, the cost of developing learning games is typically quite high compared with other uses of technology to support learning and instruction. Nonetheless, there is great interest in the systematic use of games to promote learning in adult education.

The conclusion in this case is that games be effectively used to develop interest and motivate learners but they have limited use in supporting specific learning goals and objectives, especially for adult learners. As a consequence, as with the other two cases, game-based learning should be considered a far-term and not yet mature technology. Finally, it is worth mentioning that the use of the phrase 'serious games' to refer to game-based learning does disservice to educators and to educational research. That phrase suggests more than is being delivered and probably more than can be delivered by the game-based learning community. It also raises unrealistic expectations about the nature of learning and education. Learning is not always fun and education should not be considered a game-like enterprise. The more descriptive phrase 'game-based learning' is appropriate and preferable if one wishes to avoid confusion and false expectations.

5. Conclusion

The conclusion of these remarks about these three emerging technologies is quite simple: they are not yet mature learning technologies although there is some promise in each case. Games can promote interest and motivation. Personalized learning is highly desirable but lacks the required supporting technologies (e.g., learning analytics) to be effectively deployed on a large scale. MOOCs can be used effectively to support existing learning and instruction, but as a stand-alone technology they fall short as there is little or no learning guidance, formative feedback, and overall assessment. When those elements are added, it is likely that MOOCs will have a more significant impact.

One final comment should be made at this point. These remarks are somewhat skeptical and cautionary in nature. The reason for this is that educational technologists have all too often become advocates of the newest technology and overestimated how that technology would impact and reform educational practice. As a professional discipline, educational technologists need to become more evidence-based and scientific and less advocacy oriented. My apologies to the many I have offended by these remarks, but I make them so that as a profession we might be taken more seriously and have more impact on learning and instruction on a significant scale.

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