The Song Remains the Same:

Looking Back to the Future of Educational Technology

By Punya Mishra, Matthew J. Koehler, and Kristen Kereluik

> I had a dream / Oh, yeah / Crazy dream, uh-huh / Anything I wanted to know / Anyplace I needed to go … Everything that's small has to grow / And it has to grow!
>
> — *The Song Remains the Same* by *Led Zeppelin* (1976/2007)

> Those who cannot remember the past are condemned to repeat it. — *George Santayana* (1905, p. 284)

Many would agree with this sentiment: "Today the world of the learner is almost unbounded. He [*sic*] must acquire facts relating to a bewildering variety of places and things; he must acquire appreciations of far-reaching interrelationships. The curriculum and methods of teaching must undergo a continuous appraisal. New subject matter and new devices for instruction are being scrutinized for their potential contributions to the learning process."

What is interesting about this quote is not *what* it says but rather *when* it was written. This statement is not referring to the "net generation" or to the first "computer generation" This statement was written in 1933! It resonates even today. We are all aware of the seemingly unbounded world that we live in, connected by Internet cables and satellites that enable widespread access to virtually anyone, anywhere, and to the vast array of human knowledge. Present day circumstances may seem different, yet over 70 years later the call to educators is the same—adapt to meet the needs of our rapidly changing technology.

In this essay we seek to examine the historical as well as the current demands and promises of educational technology. Broadly speaking, we define educational technology as the study and practice of facilitating learning and improving performance by creating, using and managing technological processes and resources. We discuss the rapid change of educational technology and what this means for educators. To begin to forge a new path that does not merely retrace the past, we look towards the future while offering different ways to frame our thinking about educational technology.

The song remains the same: An historical look at educational technology

Throughout history new technologies have been hailed as the "next, best thing." Understandably, these changes also bring promises to revolutionize society, including education. In 1933, the technological revolution that excited Frederick Devereux enough to write the quotation at the start of this essay (Devereaux, 1933, p. 1) was the "talking picture." He believed that "the introduction of the use of the talking picture into education may prove to be an event as epochal as the application of the principle of the wheel to transportation or the application of steam power to the industrial age" (Devereux, p.101).

Devereux is not alone in proclaiming revolutionary changes in education resulting from technological advances. Similar arguments have been made for other technologies as well (see Reiser, 2007 for a good review of the history of educational technology). The overhead projector was "opening new doors for teaching sci-

ence" (Schultz, 1965) by offering a new technology to present information to students. Recently, books such as *Toys to Tools: Connecting Student Cell Phones to Education* (Kolb, 2008) advocate the educational benefits of cell phones and offer classroom exercises that utilize their unrealized potential. Others claim that networking technologies will make "men into bandwidth angels," that will allow us to fly, "beyond the fuzzy electrons and frozen pathways of the microcosm to boundless realm" (Gilder, 2008).

It is in the midst of such hyperbole that this historical look-back becomes important for two reasons. First, even though our moment in history may seem unique, the trends and issues are similar in many respects to those of earlier generations. Second, looking back brings a level of humility to the discussion about the effects of technology to educational practice. It is sobering to think about what the next generation will think about our "cool tools" and their impact on education. We must be sensitive to the fact that just as the quotes from Devereux seem over the top, quaint, and outdated, what we say today may seem just as silly to people 50 years from now. It is certain that in 20 years our thoughts on how cell phones can change education will be regarded the same way Devereux's thoughts on *The Educational Talking Picture* appear today.

Ultimately, the revolutions in education promised by historical innovations were not realized, and a sense of déjà vu and humility gives insights into the root causes of unrealized visions of change. We argue that this is not because innovations do not offer new possibilities, new instructional strategies, or even because the technologies are not available. We believe that they fail for three reasons. The first is that using the newest technologies such as *cell phones* or *talking pictures* in ways that are instructionally effective requires specific knowledge of how the technology can be used for pedagogical purposes. Teachers are busy people with many goals competing for their time. Educators who are not skilled beyond basic usage will need to learn both the technology as well as how to use it instructionally—a completely different skill.

Second, the use of new technology often faces resistance from educators who believe that they perhaps do more harm than good. Examples of technology resistance are as old as technological innovation. Thomas Edison thought that movies would mean the death of textbooks. Socrates is quoted as saying "if men learn this [writing], it will implant forgetfulness in their souls; they will cease to exercise memory because they rely on that which is written, calling things to remembrance no longer from within themselves, but by means of external marks." It is hard to imagine writing as a threat to modern education, but Socrates' concern was very real and strikingly similar to the argument presented by Nicholas Carr is his 2008 *Atlantic* article "Is Google making us stupid?" arguing that the Internet has a negative impact on the ways in which we think and how we read.

Third, and maybe most important, we believe that most innovations have focused inordinately on the technology rather than more fundamental issues of how to approach teaching subject matter with these technologies. We believe that as educators we need to develop flexible and robust knowledge frameworks that are not dependent on the specific affordances of a particular technology, but rather connect to powerful ideas about teaching and learning.

The song remains the same, but the tempo keeps changing: The rapid change of technology

Today's discussion of technology and its role in education takes on even greater significance because of the rapid rate of technology change (Kurzweil, 2005). It is astonishing to realize that the Internet is still relatively young! The first browser to be used by "non-geeks" and which opened the web to the general public was Mosaic, and that was introduced only 16 years ago in 1993 ("About NCSA Mosaic", 2009). The Internet has transformed from simple IRC protocols that allowed information to be shared through plain-text chatrooms to the media-rich, user-developed content sharing mechanisms that we call Web 2.0. Highly acclaimed educational technologies emerge at an ever-increasing pace. This speed of technological evolution may be educational technology's unwitting Achilles heel.

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If technology is always changing and jumping from one "revolutionary" invention to the next, then, in the time it takes to learn how to use that technology, it has already become obsolete. This rapid rate of change means that there is increasing pressure on teachers to learn new ways to integrate technology with their teaching. A few decades ago, teachers could expect

that the technologies they used for teaching (e.g., blackboards, TV, video, over-head projectors) would remain reasonably stable through their careers. That expectation is clearly unrealistic for today's teachers and for generations of teachers to come.

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There is a tendency to suggest a return to basic principles; to focus on teaching and learning while separating it from the technologies we use. Research indicates, however, that not keeping up with the technology is socially counterproductive in the long run. David Brooks, writing for the *New York Times*, cites economists Goldin and Katz (2008) from their book *The Race Between Education and Technology:*

> The pace of technological change has been surprisingly steady. In periods when educational progress outpaces this change, inequality narrows. The market is flooded with skilled workers, so their wages rise modestly. In periods, like the current one, when educational progress lags behind technological change, inequality widens. The relatively few skilled workers command higher prices, while the many unskilled ones have little bargaining power (Brooks, 2008).

That is, one way of improving education is to take advantage of the potential offered by new technologies. Not doing so can have severe consequences. Goldin and Katz (2008) assert that many educators lack technology implementation skills. Keeping up with technology requires continual learning and education. Teachers who do not keep up with the latest educational technologies (talking motion pictures, overhead projectors, cell phones, etc.) will almost certainly fall behind, and unfortunately, stay behind.

In a review of the Goldin and Katz (2008) book, Kling and Merrifield (2009) note that in business, not keeping up with technology can be extremely costly. They say:

> The software spreadsheet program Microsoft Excel is upgraded every few years. When an upgrade occurs, some of the functions are reconfigured. Think of Excel as a metonym for the edge of technology available for widespread commercial application. Very often we acquire an upgrade but prefer to use the old version. If skills do not keep up with technology, one might be less productive with the new version. Moreover, even if one's absolute productivity remains the same, if other users gain the skills suited to the new version, one falls behind relative to other workers (Kling & Merrifield, 2009, p. 3).

With every change in technology, teachers have a choice to upgrade and invest time in learning new functions or not upgrade and work with what is available. Choosing the latter maintains productivity for a while, but in the long run hinders productivity for two reasons. First, the potential to improve efficiency with new functions remains undiscovered. And second, others who adapt the new capabilities improve productivity in comparison to those who do not. As Kling and Merrifield (2009) say in their review, this entire process "is a race between individuals in their levels of capabilities, but it is a race whose terms are affected by technological advancement" (p. 3). This race keeps getting faster and with a greater number of obstacles.

Expecting teachers to know each and every piece of new technology is a difficult goal to achieve and is an approach that is fundamentally doomed to failure. There are too many technologies making this view impractical. This is not to say that *The Educational Talking Picture, Toys to Tools,* and other educational technology guidebooks do not offer unique and even creative ways to engage with students. However, this focus on specific technologies instead of broader, generative frameworks of thought will always be limited, preventing us from keeping up with the rapid pace of change of technology and ultimately make us fall behind.

Furthermore, learning technical skills alone is not sufficient—learning how to integrate technologies into teaching is equally important. We have argued for a new way of thinking about technology that allows for flexibility of thought, a willingness to tolerate ambiguity, and a willingness to experiment with how technology can best be used to teach subject matter in powerful ways. Teacher educators should focus on instilling these traits in pre-service teachers instead of having them master specific tools.

This new approach calls for creativity and ingenuity on the part of teachers and teacher educators, as well as a way of looking at educational technology that goes beyond continuously "chasing" the latest and greatest innovation. It is only by paying attention to deeper ideas and more enduring ideas of teaching (while being

open to new possibilities being brought about by new tools), and by developing strategies and approaches that are flexible and context sensitive, that we can best serve our students.

A new song: New ways to think about educational technology

The Technological Pedagogical Content Knowledge (or TPACK) framework (Mishra & Koehler, 2006) is a step towards understanding what makes a technology an *educational* technology by emphasizing that educational technologies exist in the interplay between pedagogical knowledge, content knowledge, and technology knowledge. TPACK addresses the necessity of looking past just the technical aspects of educational technology and focusing instead on the overlap between pedagogy, content and technology (Koehler & Mishra, 2008). The importance of the interplay between these three knowledge domains was realized also by the author of *The Educational Talking Picture* who stated, "Probably the most complex problem in connection with the use of any mechanical aid to instruction is the integration of the use of the aid with teaching method and the curriculum" (Devereux, p. 103).

How does the TPACK framework offer a new way of thinking about educational technology? First, by stressing how technology interacts with pedagogy and content, innovations are not necessarily relevant for teaching. Instead, emphasis is put on evaluating the entire teaching performance, not just one aspect of it (e.g., technology). Second, using the TPACK framework helps educators reason about which technologies are worth learning; not to learn every technology and then figure out how to apply it. Instead, educators should be able to quickly evaluate new technologies in terms of how they will present content or facilitate pedagogy.

A recent report about students in Italy computing the distance to the moon using publicly available data is a great example of how teachers can leverage new technologies to develop pedagogical approaches to content (Girlanda, 2009). In this project, students in an Italian high-school worked in ten groups of two or three students under the guidance of a teacher, to analyze an MP3 recording of the conversation between Neil Armstrong on the surface of the moon and ground control in Houston. They took advantage of an echo on a recording of sentences from Earth which were retransmitted via Armstrong's helmet speaker through his microphone and back to Earth. They used the open source audio editing program Audacity to accurately measure the echo's delay and used that data to compute the distance to the moon. Though this process sounds easy (at least in the brief way in which we have described it), it is in fact a task fraught with ambiguity and the possibility of error; something the teachers had to keep in mind as they worked with the students. For instance, consider the issue of measuring the time delay of the echo. As the report describes it:

> Several methods of measurement of the time delay of the echo can be adopted and the students were given freedom to devise the more appropriate one: some chose to mark the times at the beginning or at the end of the syllables, others at the maximum of the signal within a syllable. Each measurement has an associated uncertainty that the students were asked to estimate as well (Girlanda, 2009, p. 3).

Different student groups chose different methods of measurement and then agreed to take the average of 10 measurements for computing the distance to the moon, which they did so very accurately. In fact, at the level of accuracy afforded by Audacity, and the range of audio recording available from the NASA website, the class could even detect the effects of the ellipticity of the orbit of the moon!

We see this as a great example of a creative use of technology to teach fundamental science ideas. The question that we are interested in, however, has to do with what a teacher needs to know in order to *come up with* such a project? Clearly, once a project has been developed, other teachers can replicate it in their own classrooms. What is important, from our perspective, however, is to understand the creative leap that led to this idea in the first place. What *do* teachers need to know? In this particular case, the teacher first needed to have a deep knowledge of the *content* to be covered, physics and mathematics. Also, the teacher needed good knowledge of *technology* and what could be done with it—not necessarily specialized "physics" software (though they did use a planetary simulation for parts of the research), but general use software like Audacity to conduct the audio analysis. How many teacher educators today would know that Audacity could be used to teach physics? This illustrates the spe-

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cial kind of technology knowledge that teachers need to be successful. Teachers have to be willing to learn new technologies, always seeking connections between these new technologies and their pedagogy.

Third, teachers need knowledge of pedagogy—knowledge of how to teach—in order to accomplish these kind of activities. The report of this experiment clearly shows that the instructors brought to bear a great deal of sophisticated knowledge of teaching to the classroom context. For example, teachers had detailed understanding about how groups should be set up to find the right balance between structure (introducing the problem) and freedom (students devised appropriate methods of measurement of the time-delay).

The most important form of teacher knowledge goes beyond each of these pieces of knowledge taken in isolation. *What made this project work is that it brought together content, technology, and pedagogy in a creative, integrated manner.* This is TPACK. This is not just knowledge of physics, software, or teaching but rather the ability to bring together the often contradictory demands of these disparate domains to develop a powerful educational experience. This is the art of teaching. This is good design. Girlanda (2009) describes how the teacher brings together physics, pedagogy, and the role of technology in an integrated whole:

> The experiment that we have reported represents an example of "open" research-oriented activity, in which no "correct answer" can be anticipated a priori. This aspect should be emphasized whenever possible in the teaching of physics, since it gives students the flavor of what physicists do in their experimental or theoretical work. Another aspect of our experiment—common to most of present-day experimental research in physics—is the analysis of raw data (in our case the audio registrations) by means of sophisticated software, which gives the opportunity to extend the discussion on the "error sources" (Girlanda, 2009, p. 6).

Finally, it is amazing that the results of an experiment conducted in a school in Italy, based on the analysis of raw data downloaded from a website in the United States, using free open-source software built collaboratively by volunteers from across the world, can be accessed by anybody within a week of its publication from an e-print service that offers knowledge freely to one and all! This is the world that today's educators live in. This is the world for which we have to prepare the next generation of educators.

Conclusion

The TPACK framework emphasizes the role of teachers as decision makers who design their own educational technology environments as needed, in real time, without fear of those environments becoming outdated or obsolete. Using this approach, teachers do not attend to specific tools, but instead focus on approaches to teaching that endure through change in technologies, content, or pedagogies. Teachers with flexibility of thought, a tolerance for ambiguity, and willingness to experiment can combine traits that perfectly design and tailor their own educational content, pedagogical, and technological environments.

David Passig recently wrote on the topic of melioration, or "the competence to borrow a concept from a field of knowledge supposedly far removed from his or her domain, and adopt it to a pressing challenge in an area of personal knowledge or interest" (2007). Passig's melioration is similar to the traits advocated by the TPACK framework. Passig acknowledges the importance and necessity of the cognitive skill of drawing on knowledge from varying domains and combining them in unique and effective ways.

According to Passig, melioration is a skill that affords teachers the flexibility to experiment with a vast array of technologies to meet their specific educational needs. The use of an audio editing program as a data analysis tool (in the moon experiment described above) is a great example of melioration. Novel frameworks and concepts like TPACK and Passig's melioration are starting to look at educational technology in a new way. These new perspectives focus on overarching cognitive skills, competencies, and creativity rather than technical understanding and functional knowledge of specific technologies.

We wonder how far current teacher preparation programs are telling pre-service teachers what an educational technology is rather than empowering them to experiment and create their own. A new focus needs to take root, one characterized by creativity and flexibility of thought and experimentation by educators with their own educational technology designed to meet specific, immediate needs. If technology is truly to be beneficial to education, the power and potential of educational technology must be acknowledged to reside within educators and not within objects. We must foster in future educators new skills designed to harness the potential of our "unbounded" world.

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