The Transformation of Learning with Technology

Learner-Centricity, Content and Tool Malleability, and Network Effects

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Educational visionaries and reformers have long predicted a significant transformation of teaching and learning that would be facilitated by technology, essentially providing every learner with the equivalent of a personal tutor. Technology implementations in education, however, have consistently fallen short of achieving these lofty aims. The authors argue that this failure stems from a penchant to implement technology in ways that automate that past. Instead, we must champion learning technologies that are learner-centric and malleable, such that they address the needs of individual learners and can take advantage of the power of network effects. Only then will we realize the long-awaited transformation.

Introduction

The 1960s was a decade of upheavals, but it was also a decade of dreams, full of grand visions of a better world. At the beginning of that momentous era, actor Bob Cummings helped fuel the national fascination with flying cars when he purchased and piloted an Aerocar on his TV show ("Chuck," 2008). With similarly futuristic vision, Stanford philosopher Patrick Suppes predicted in a 1966 *Scientific American* article that "in a few more years millions of schoolchildren will have access to what Philip of Macedon's son Alexander enjoyed as a royal prerogative: the personal services of a tutor as well-informed and responsive as Aristotle" (Suppes, 1966, p. 201). Unfortunately, both visions of the future have proven too optimistic. The sky is not filled with flying cars and every child is not blessed with the services of their own private "Aristotle."

Why haven't our most visionary dreams been realized? Why hasn't technology dramatically improved learning? The promised technology-driven transformation of education seems tantalizingly just out of reach. We're left to ask, metaphorically speaking, "Dude, where's my flying car?(!)" We argue here that educational reformers and academic technology strategists are waiting in vain for the promised revolution in teaching and learning because we have consistently, almost single-mindedly, used technology to automate the past instead of employing our best thinking and efforts to create a new future. Specifically, otherwise well-intentioned reformers have missed opportunities to create learning content and tools that are open, modular, and interoperable.

Because "openness" has taken on various and sometimes ideological meanings, it is appropriate for us to clarify what we mean by the term "open." Our intent is to describe tools, processes, and frameworks that interoperate in an open fashion to create and deliver content that is itself accessible, flexible, and repurposable. We do not hold that tools or content need to be "free" (as in "no-cost") to be open. For example, a closed source, commercially provided tool might have an open architecture that is extensible via APIs or Web services. In contrast, an open source tool might be very proprietary in terms of the kinds of applications and databases with which it will interface; thereby creating content that is quite closed. We contend that the prior is legitimately more "open" than the latter. The nature of openness that matters most to learners, teachers, and the institutions that support them is the ability to quickly and easily find, customize, and implement the right tool or content for specific learning contexts. By this view, open source software or open content (i.e., freely distributed under a Creative Commons license) is not inherently better than or normatively superior to commercially provided and licensed tools or content. Supporting effective, dynamic learning is the primary aim—the nature of the tools used and their source are both of secondary importance.

This being said, we believe that openness, including the kind of radical new openness championed by the open source and open content communities, is a

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critical enabling factor in the transformation and improvement of learning. Imagine a world in which anyone, anywhere, could use exactly the right tools and content at the right time, seamlessly with the other tools and content they already use, to solve their teaching and learning challenges. Can there be any doubt that the prospects for online teaching and learning would improve? Accordingly, we believe that it is crucial to promote openness *combined with* the principles of modularity and interoperability to facilitate the development of new tools and methodologies for reusing, remixing, and mashing-up content to achieve learning goals in ways never thought possible.

By leveraging such ideas, teachers and learners can more fully take advantage of the network effect in technology by enabling learning communities. Significantly increasing the output in learning content has the potential to fundamentally alter the learning landscape, just as the Web in general has changed the information landscape. Finally, we argue that perpetuating teacher-centric, didactic models of education prevents fundamental, paradigm-altering changes in learning and accompanying role changes. We conclude that teachers and academic leaders must embrace these principles—namely openness, modularity, interoperability, the network effect, and learner-centricity—for the full potential of learning technology to become widely available, usable, and affordable.

The magnitude of this potential is illustrated by research from the 1980s that ascertained the value of one-to-one tutoring (Bloom, 1984). Benjamin Bloom, perhaps best remembered for his "Taxonomy of Educational Objectives," quantified what Aristotle and his predecessors, Socrates and Plato, no doubt believed: that one-to-one tutoring is the most effective way to facilitate learning. While the Industrial Revolution's "mass-production" methods of learning have dramatically expanded our capacity to educate more people, the quality of that education has not been on par with personalized instruction. Indeed, Bloom quantified this gap, concluding that students learning with a tutor had on average an advantage of *two standard deviations* above the mean of "mass" educated students. Bloom recognized the obvious impracticality of the implications of his finding. He declared that an "important task of research and instruction is to seek ways of accomplishing this under more practical and realistic conditions than the one-to-one tutoring, which is too costly for most societies to bear on a large scale." Bloom dubbed this challenge the "2-sigma problem" (Bloom, 1984, p. 4), which led him and his students to attempt to devise methods of group instruction that are as effective as one-to-one tutoring.

The Nature of the Dilemma

While the sort of individual, computer-based tutoring Bloom envisioned is possible to some extent (Fletcher, 2008), the widely available and affordable implementation thereof remains more a dream than a reality. To argue, however, that technology hasn't changed, and at least marginally improved, teaching and learning would be nonsensical. Indeed, with well-conceived Google searches, learners today can at least partially realize Suppes' vision— they can effortlessly access far more information than even a sage such as Aristotle could have ever accumulated and retained through a lifetime of study. Efficient access to information, however, is not the equivalent of responsive human tutors, the kind of "teachers" Suppes predicted would be readily available to children everywhere.

Suppes was not alone in making such optimistic prophecies about the impact of computers on education. In 1968, for example, George Leonard described computer-based learning in the most glowing of terms. Both his rhetoric and the title of his book on the subject, *Education and Ecstasy*, are much in keeping with the writing of someone known as the "granddaddy of the consciousness movement" (Gelman, 1991). After visiting schools across the country, Leonard reflected on the wrongs that fill the world, "war, disease, famine, racial degradations, and all the slaveries man has invented for his own kind," concluding that none of these "is deeper or more poignant than the systematic, innocent destruction of the human spirit that, all too often, is the hidden function of every school" (Leonard, 1968, p. 110). In the chapter entitled "Visiting Day, 2001 A.D." he described an ideal future in which personalized computer-based learning would be the norm. The computers in his vision would implement "Ongoing Brain-wave Analysis" and could teach learners the basics of any subject area in a fraction of the time required in conventional schools, encouraging "uniqueness rather than sameness in learners" (p. 145). The biggest challenge that Leonard foresaw in such a world would be "what to do with the extra time gained in the new mode of learning" (p. 144).

Although the conundrum observed by Bloom is less transcendental than Leonard's vision of schools in our day, the comparison between vision and reality is startling in either case. Not only has "Ongoing Brain-wave Analysis" not materialized, but schools around the world struggle with the limitations of outdated systems for learning. Not only do schools continue to fall short of bridging the 2-sigma gap, but their performance is disappointing on many levels as they fail to meet even the basic education needs of the Information Age.

This is especially true in the United States, where students are falling further and further behind many of their counterparts around the world in science and math, as measured by an international exam sponsored by the OECD Program for International Student Assessment (PISA) ("Something," 2007). This report provides a discouraging view of American education, prompting three K–12 leadership groups to warn that technology was not playing a sufficiently important role in education in the United States:

> How will we create the schools America needs to remain competitive? For more than a generation, the nation has engaged in a monumental effort to improve student achievement. We've made progress, but we're not even close to where we need to be.
>
> It's time to focus on what students need to learn—and on how to create a 21st century education system that delivers results. In a digital world, no organization can achieve results without incorporating technology into every aspect of its everyday practices. It's time for schools to maximize the impact of technology as well. (SETDA, ISTE, & P21, 2007, p. 2)

A host of scholars and educational leaders have argued for decades that technology can and should play a wide and effective role in addressing learning shortfalls (Bunderson & Abboud, 1971; Bunderson *et al.*,1984; Fletcher, 2003; Kulik & Kulik, 1987). Indeed, a brief review of 1967 issues of *Educational Technology*, for example, reveals a very interesting picture, one filled with hope regarding what digital technology would be able to do for education. Young (1967), for example, observed:

> Since knowledge is multiplying at a geometric rate, it is inconceivable that students of the future will be fed this information on the same basis that they are today. Instead, facts will be available when needed. The teacher will not stand in front of a group and lecture, giving information or checking the children's production. The pupil studying the problems will use a teacher as a consultant, and paraprofessionals, the library, the computer, and other materials will be used as resources when he needs them. (p. 4)

Other observers predicted similarly profound changes, including (1) the abolishment of grade levels, (2) significant changes in the role of the teacher, and (3) the implementation of new learning methods and learning technology ("Experimental," 1967). One university president lauded the availability of a single computer "solely for use by our 5,000 undergraduate and graduate students" while the chairman of that university's computer committee declared, "The computer is becoming integral to 20th Century society. It is not only an instrument for the scientist and engineer, it is also a tool for business and professional men" ("Computers," 1967, p. 19). These visionaries believed the future of research, learning, and business would all be fundamentally changed by technology.

Finally, the Associate Commissioner for Research of the U.S. Office of Education, R. Louis Bright, predicted in 1967 that: "programmed instruction, instructional TV, computerized instruction, and use of other new media will increasingly be important factors in providing education of the scope and depth our young people need. How else can we provide the necessary sustenance for increasing enrollments, characterized by a multiplicity of threads of interest, wide variation in learning styles and rates of progress, and great diversity of motivation and goals" (Bright, 1967).

These visions of dramatic learning improvement have been largely unrealized, despite the passage of four decades. But the visionaries persist in predicting a brighter future. More recently, at the height of the dot-com bubble, such enthusiasm even made its way to the pages of *Business Week*, in the form of a quote by Howard Block, an analyst at Banc of America Securities, who stated that "There will be a tremendous migration away from classroom learning to online learning" (Symonds, 2000). The article also cited widely repeated predictions that education would be the next "killer app" for the Internet. More recently, Secretary of Education Margaret Spellings convened a series of three roundtable discussions involving not only individuals from various quarters of education and from technology companies but also students. The report from the proceedings of those meetings concluded that new Internet and Web 2.0 technologies made available via affordable computing platforms "can help us redefine the way education is provided to students so that learning can take place anytime, anywhere, and at any pace" ("Harnessing," 2008, p. 3).

Such anticipation notwithstanding, even cursory visits to a randomly selected sample of classrooms at any level of American education would quickly reveal that there is neither a mass migration afoot nor a "killer app" that is transforming education. Mary Ann Wolf, the executive director of State Educational Technology Directors Association (SETDA), lamented that the level of benefits received from technology use in our schools is nowhere near what it should be: "Our educational system has a long way to go before the potential of technology to improve teacher quality, increase rigor, and maximize efficiencies is realized" ("Partnership for 21st Century Skills," 2007). Worse yet, some observers maintain that not only has the potential of educational technology not been reached, but a great deal of money is being wasted on purchasing educational technology that is either not being used to its full potential (Cuban, 2001) or is in fact being used when it should not be (Stoll, 1999).

How and why have we fallen short? If the optimistic prognostications of technology-hawking reformers were realized, Larry Cuban argues that technology should have visibly improved education in three ways: (1) schools should be more effective and productive, (2) learning should be more engaging and connected to real life, and (3) students should be better prepared for the workplace (Cuban, 2001, pp. 13–15).

To test the validity of these expectations, Cuban examined the impact of massive technology investments in K–20 education in Silicon Valley. His conclusions are not terribly optimistic—he found little evidence that the resulting technology infusion in a very supportive environment has yielded any significant changes in teaching strategies (p. 130). On the contrary, Cuban concluded that, by and large, "teachers used technology to maintain existing practices" rather than to "revolutionize" the way they teach their students (p. 138).

Once again, history repeats itself. Teachers in Silicon Valley, where resources and attitudes are favorable to a technology-enabled teaching and learning revolution, have responded to new technologies much like their predecessors responded to film, radio, and instructional television. In those cases the adoption curve was slow, but over a long period of time, even the most stubborn "laggards" began using films and television in their classrooms. But the new technology did not lead to the transformation of teaching and learning practices. Rather, new technologies became "peripheral to the daily routines of teaching and learning," much like today's new technologies are for today's teachers (p. 140). Perhaps even more worrisome are the results Cuban uncovered at Stanford University. Notwithstanding the university's investment in thousands of computers, network connections in dorm rooms, and computer labs, teaching and learning activities remained largely unchanged: "Lecturing still absorbs more than half to two thirds of various departments' teaching practices.…These traditional forms of teaching seem to have been relatively untouched by the enormous investment in technologies" (p. 171). Similarly, Secretary of Education Spellings' roundtables concluded that a major part of the challenge of the implementation of new technology is that it "has been applied to the outside of the education process, rather than as a critical tool in revamping the process itself" ("Harnessing," 2008, p. 9).

Cuban's analysis and the conclusions of the Department of Education roundtables lay bare the fundamental challenge faced by educational technology strategists, policy-makers, and reformers. The vast majority of educational technology implementations to date have been focused on making things more effective and efficient for institutions and teachers, and not necessarily on improving outcomes for learners. We should not be surprised, then, that educational technology has not significantly transformed and improved learning.

Although the application of computers to education has greatly outpaced the availability of flying automobiles, the impact of digital technology for learning has been significantly less profound than was anticipated by Suppes, Leonard, and others. Indeed, the kinds of computerized tutors reformers have envisioned are still far from providing individualized learning support tailored to the needs of individual students, at least beyond a few limited example demonstrations. And so we're left disappointed. Our cities' skies are not filled with airborne cars, and human beings continue to learn in about the same ways they did forty years ago.

The Tipping Point: Facilitating a Transformational Learning Revolution

If technology has thus far failed to yield revolutionary changes and improvements in teaching and learning, what sorts of technology changes or implementation approaches might make a difference in the future? While technology and content standards are important, we believe that merely refining standards and implementing them more consistently and more widely will not, in isolation, dramatically improve, let alone revolutionize, teaching and learning. Nevertheless, one is left with the frustrating impression that all of the necessary puzzle pieces are on the table; we have but to figure out how to put them together. So how do we turn small, relatively isolated examples of successful technology innovation into a revolutionary transformation of teaching and learning?

This is precisely the kind of question Malcolm Gladwell tackles in *The Tipping Point* (2002). A tipping point, he explains, is that "one dramatic moment in an epidemic when everything can change all at once" (Gladwell, 2002, p. 2). For Gladwell, an epidemic need not be a negative health phenomenon, like a virus. Instead, it can be a sudden change in public attitudes that results in lower crime rates, or the sudden adoption of a new fad by millions of teenagers. His primary thesis is that there are critical junctures in time or space at which relatively small, insignificant phenomena can become epidemics—IF the right "tipping" factors are present.

So what exactly does a tipping point look like? First, it's a point in time at which unusual or uncommon practices turn into "contagious behaviors," morphing from the ordinary to the viral in an instant (p. 7). Second, small, seemingly insignificant things can cause the tip, resulting in "big effects" (p. 8). Lastly, when something tips, the change happens in one dramatic moment (p. 10). Even casual observers of the impact of technology on teaching and learning might sense that we are at or near a tipping point. But we are left to wonder what "contagious behaviors" and "small, seemingly insignificant things" will cause the tip to occur?

Gladwell identifies three key "causes" of a tipping event: (1) the influence of a few key individuals, (2) the "stickiness" of the message, and (3) the context in which all of this plays out (see the *Introduction*).

First, Gladwell argues that the "the law of the few" is crucial to every epidemic. There are almost invariably three small but important groups of people who help bring a phenomenon to its tipping point. First, there are the "mavens," the enthusiastic few who are the early adopters of a new behavior, idea, or product. Second, there are the "connectors," individuals who have the rare ability to link people, ideas, and opportunities into synergistic patterns. And, finally, there are the "salesmen," those who have the ability to "sell" ideas to those who remain unconvinced that a new idea is riskworthy.

Judging from the number of conferences, journals, and other publications on teaching and learning improvement, there appear to be plenty of instructional technology mavens. It is therefore interesting to wonder why the efforts of these risk-takers have not resulted in a technology-driven revolution in teaching and learning. Is it because their success stories are not being shared with others in generalizable ways? Is it because the "mavens" aren't in touch with the right "connectors" and "salesmen" who can help spread their message?

Or perhaps is it because the message of change just isn't sticky enough to incite the sort of revolution that is going to be necessary for real change to take place? In simplistic terms, is the proverbial "elevator pitch" from a technology maven, connector, or even a salesman memorable or interesting enough to "stick" in the mind of a colleague? While the mavens are obviously enamored with their technological innovations, observers of the mavens might simply fail to "get" what the mavens are doing or understand the inherent value in those activities. Over and over, scholarly research on the impact of such innovations shows "no significant difference" between using traditional methods and new technologies. For example, this phenomenon is the subject of a Website that documents the findings of "no significant differences" (NSD) in student outcomes between alternate modes of education delivery (Russell, 2008). What is there in this message to motivate non-consumers to implement technology in their courses? Apparently not much. Most teachers are likely to perceive the costs (particularly in terms of their time) of producing and distributing technology-enhanced curricular materials to be higher than the perceived payoff.

In addition to these barriers, the current education context itself might not be conducive to a teaching and learning revolution. The reward (and punishment) structures and mores for teachers tend to promote caution and *satisficing* rather than experimentation and innovation in teaching and learning. Moreover, the costs of producing, delivering, and consuming new curricular materials enabled by new technologies might simply be too high. As a result, perceptions are often more important than reality when it comes to the context being right or wrong for a tipping point. For example, when lots of windows are broken in a neighborhood, a perception of disorder and lawlessness can trigger a crime epidemic. Gladwell maintains that human beings are "exquisitely sensitive" to such contextual changes (p. 140). Thus, the right change, albeit microscopic, can be enough to cause a tip which results in dramatic transformations. We are left wondering about the educational environment or context in which teachers, learners, and leaders think about and implement technology. Are there contextual factors holding us back?

Transformation and Context

While we are just as anxious as any of our readers to discover what might bring about a much-awaited tipping point in educational technology, it is crucial to recognize that an important first step is to proactively create a context more conducive to the sort of dramatic changes that can yield improvements of the 2-sigma magnitude. For starters, teaching and learning tools and content must be made more available, affordable, and usable than they are today. That means it is not sufficient to merely create technologies that are capable of facilitating learning. In addition, such technologies have to be effectively and efficiently deliverable to ALL learners.

Compared to the pace of what some call "Internet Time," the implementation and transformational impact of educational technology might seem painfully slow. A look to the past is instructive. Other revolutionary learning technologies have had to overcome many of the same challenges as today's new educational technologies. For example, it is hard to imagine a "technology" more revolutionary than writing. But writing was not universally embraced by the intellectuals and teachers of the day. Socrates himself, speaking through the voice of Thamus, the king of Egypt, bemoaned:

> The specific which you have discovered is an aid not to memory, but to reminiscence, and you give your disciples not truth, but only the semblance of truth; they will be hearers of many things and will have learned nothing; they will appear to be omniscient and will generally know nothing; they will be tiresome company, having the show of wisdom without the reality. (Plato, 370 B.C.)

With luminaries of such stature lamenting the invention of something as fundamental as writing, it is abundantly clear that human beings have always been conservative and resistant to "technological" change.

Although such resistance to change limited the impact of writing on average people for centuries, even after the invention of movable type in the Western World, basic human conservatism was not the only factor that hindered its adoption. As with any technological revolution, changes in how things were done—changes in context—were just as necessary for the broad emergence and use of books, as illustrated by the following story imagined by the French videodisc pioneer, Georges Broussaud:

> King Charles VII of France wanted to learn of the high technology recently invented by Gutenberg, so he sent his emissary on a fact-finding trip. The emissary returned several months later to report on what he had found. "Well," said the King, "What do you think of this new, high-tech stuff called movable type?" "Interesting," replied the emissary. "Only interesting?" said the King. "Yes, Sire. It is very interesting indeed, but it is going nowhere," said the Emissary. "Why on Earth not? If it is interesting, why isn't it going anywhere?" exclaimed the King. Replied the Emissary, "First of all there is no distribution channel, no way to insure the sale of the books that would be printed. Finally, Sire, people can't read!" (Bush, 1989, p. 11)

What eventually happened, of course, was not far removed from this story. While it is said that Gutenberg's invention took place sometime between 1440 and 1455, it was not until the early 1500s that book shops became more widely available, and then only in the larger cities. In order for writing in this form to move beyond expensive, hand-copied volumes chained to the lecterns of the Sorbonne from which lectures were delivered ("lecture" in French is quite literally "reading"), fundamental changes were necessary. Although technological improvements were certainly essential, the widespread implementation of books did not happen until attitudes and expectations were also changed.

Taken together, this means that writing did not reach its "tipping point" until key contextual factors changed, i.e., it became widely available, affordable, and usable. These are common contextual necessities that influence the adoption and accessibility of any particular innovation. For example, one of the most important changes in context that served as impetus for making writing technology more accessible to the average man or woman was a growing democratic demand for access to more and more content. The people wanted—even demanded—the ability to read what the elites were reading (Graff, 1991, p. 113). Only then did the organizations (primarily religious ones) that determined how writing technology would be used become predisposed to its broader implementation. Note that necessary changes in roles and organizational structures *followed* the tipping point in this instance—they did not precede it. Such will likely be the case for today's digitally-based educational technology. Similarly today, as the democratic demand for access to more and more learning content and learning opportunities grows, the context will become ripe for a transformation of teaching and learning.

A Principle-Driven Approach to Technology in Education

The history of the coming of books onward from the Fifteenth Century provides numerous lessons for understanding the various changes that must take place before new learning technologies can have their predicted impact and bring about an associated shift in its focus from teaching to learning. Even in today's Twenty-First Century, writing and printing combine to form the most prevalent educational technology in use today—books—which continue to bridge time and space, unsurpassed in many ways in their ability to disseminate knowledge and learning.

Just as was the case for books in Western Europe, the transformation of teaching and learning in education today certainly depends on the effective implementation of the right technologies. But it does NOT depend on implementing the same kinds of technologies in the same ways they have been done for the past 30 years, the past 20 years, the past decade, or even the last five years. To achieve the dramatically different results (on the 2-sigma scale) the educational community has longed for, innovators cannot persist in pursuing the same strategies that have failed for decades to yield the desired results. Instead, the only viable approach is to change the rules of the game, fundamentally altering the environment in which learning occurs. Particular technologies and technology standards are certainly part of the equation; however, no technology or standard has value in and of itself. Value comes from what is done through the implementation of those standards in the creation and use of effective and affordable learning materials.

This need to change the rules of the game was as true in the past as it is today. Printing has made learning increasingly available for nearly 600 years. The resulting transformation provides insights that can guide the implementation of technology that might challenge the pre-eminent position still held by printing and the classrooms in which it is used. These insights can be subsumed into three core principles of design that must be at the center of our discussions, debates, strategic planning, and then our implementations and integrations of teaching and learning technology: (1) learner-centricity, (2) content and tool malleability (which encompasses openness, modularity, and interoperability), and (3) the network effect.

Learner-Centricity: Changing the Focus from Teaching to Learning

If the educational establishment is likely to follow rather than lead the next educational technology revolution, from where will the energy of the revolution come? Who will create the context for a dramatic transformation of teaching and learning facilitated by new technologies? As was the case for the writing revolution, the energy is most likely to come from the masses. Despite the claim by some that a technology-driven transformation of learning is *about* to happen, there is already evidence that (1) technology use in education has increased to remarkable levels, and (2) there are many incredible educational applications in use that were never foreseen in the crystal balls of even the most visionary of scholars of years past. The more pertinent question might be: when will these technologies begin transforming the education establishment?

Perhaps soon. The authors of *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns* assert that we are rapidly approaching a tipping point in the delivery of online learning. They predict that "given the current trajectory of substitution, about 80 percent of courses taken in 2024 will have been taught online in a student-centric way" (Christensen, Horn, & Johnson, 2008, p. 102).[i] This dramatic change will be driven in large part by learners as they increasingly demand the kinds of courses they need and want in their efforts to accomplish their educational goals. Although the authors' investigation and arguments focus primarily on K–12, similar conclusions can easily be drawn for K–16, or perhaps even for K–20.

To raise the issue of student demand here is to take a calculated risk. For many, taking student demand into consideration is antithetical to the philosophy of education itself, probably at any level. According to this prevailing (but waning?) view, professors and teachers and administrators are the founts of knowledge and wisdom when it comes to deciding what students should learn, when it should be learned, and in what order. To cater to student demand, subscribers of this view argue, would be to water down and diminish the value of school-based education, essentially allowing the inmates to run the asylum.

Several key assumptions about quality educational technology, however, countervail against such a world view and guide the conclusions of this article. These are provided not as evidence of universal consensus but for the sake of discussion:

1. Educational technology can and should be used to facilitate the:
   a. definition and publication of student learning outcomes;
   b. design of the curriculum necessary to help achieve those outcomes; and
   c. delivery of the curriculum that must be developed.
2. The capacity of educational technology (both in terms of hardware and software) for individualized learner support exceeds in many ways what was imagined at the dawn of computer-based learning.
3. Educational technology can facilitate a wide variety of learning experiences for a global, distributed audience of learners.
4. Educational technology need not be implemented in a monolithic, standardized, "enterprise" fashion to be effective or efficient. Nor must the same tools be used to facilitate every course (or learning experience) by every instructor and every learner.
5. Educational technology can be successfully implemented to meet the diverse needs and circumstances of learners in a variety of contexts, e.g., traditional class-based learning enhanced with technology, hybrid courses that are part traditional/part-online, synchronous online courses, asynchronous online courses, informal (non-class) learning experiences, etc.
6. Educational technology allows, and perhaps requires, learners to adopt new attitudes, self-perceptions, and roles.
7. Just as the implementation of educational technology causes students to change how they think, act, and feel as they learn, so must teachers and educational support staff change how they approach their responsibilities.

Implicit in all of these assumptions is a clear emphasis on the needs of the individual learner. What the learner needs—and even wants—is an increasingly important variable in the design and delivery of learning opportunities. Accordingly, the educational system should refocus its technology resources and efforts at least as much on learners as it has on institutions and teachers in the past. As Christensen *et al.* (2008) have argued, learner demand for a broader variety of learning experiences will continue to drive "disruptive innovation" in education.

How should teaching and learning administrators and strategic planners respond to these demands? For starters, educational technologists need to begin thinking differently about the effectiveness of teaching and learning technology. The goals we articulate at the outset invariably drive our technology strategies, tactics, and results. Scholarly trends like the Design-Based Research movement and practical efforts like Carol Twigg's National Center for Academic Transformation *(http://www.center.rpi.edu)* are examples of the new approach we have in mind. A related philosophical challenge is to change our mindset of learning *from* technology to learning *with* technology (Reeves, 2006). Until reformers and practitioners begin talking and thinking about how teachers and learners can use technology—to work with it—to transform and dramatically improve teaching and learning, we'll be stuck with the "old wine in new bottles" that Cuban lamented in his study of education in Silicon Valley. And instead of responding to student demand for better and more flexible learning opportunities, we'll continue to respond to institutional and instructor demands for more efficiency and convenience.

As educational systems focus on student demand, the supply of quality, flexible teaching and learning content and tools will increase dramatically. Unfortunately, the market will not naturally or automatically make this adjustment as a service to would-be reformers, because students are not the direct customer of teaching and learning technologies—institutions and teachers are. Rather, we predict that as reformers shift their focus from teaching to learning, they will foment a revolution in technology that will dramatically improve learning outcomes. Not only will learning effectiveness increase, but a concomitant upsurge in learner engagement and satisfaction will become inevitable (Bourne & Moore, 2003).

Learners themselves will further catalyze this trend as they become more engaged in and assume greater personal responsibility for their own learning. Such developments depend very much on learner motivation, an often underestimated and inadequately tapped source of learning improvement. Roger Schank has argued that intrinsic motivation is the single most important contributor to student learning. In a recent talk at Brigham Young University, Schank showed a video of his grandson learning to crawl, asserting that you can learn all you need to know about learning by watching this event unfold (Schank, 2008). Because intrinsic motivation is monumentally important to the child's success, the role of the "teacher" in that particular learning context is not to explain the mechanics of crawling or even to model crawling for the child. The "teacher" (the grandfather in this case) merely placed a toy within a short crawling distance, prompting the child to make more progress in crawling in the short minutes that followed than he had achieved over the days that preceded this single learning experience.

The teacher's job, therefore, should increasingly be to enhance and leverage the learner's motivation by manipulating the environment, e.g., by placing desirable and achievable goals just out of reach, to create the ideal conditions for learning. Unfortunately, most of the educational experiences afforded to students in formal K–20 courses and classrooms rely on extrinsic motivation—grades, teacher, or peer pressure, etc. Consequently, the majority of the learning experiences that most students have during their formal careers as students are not the authentic, life-enhancing, enduring kinds of events idealized by innovators in their loftiest accounts of education. By shifting the focus in teaching and learning technology efforts away from institutions and teachers, moving it instead to learners, perhaps innovators can begin creating and providing more intrinsically motivating learning experiences to more learners.

As illustrated by the message conveyed to the king's emissary, those who will benefit from an innovation must be predisposed to the new technology's features in order for it to be usable. For books, this meant the masses had to be literate, a feat that took about 400 years! In England, for example, about two centuries after the invention of printing, two-thirds of adult males in areas close to London were illiterate, and it took another two hundred years for the proportion to be reversed in the country as a whole (Lane, 1980).

The applicability of the innovation to the needs of its users is no different today than it was during the dawn of the technology of books. Indeed, the most important principle impinging on the effectiveness of any technology has less to do with the technology itself than it does with its ability to address the capabilities and needs of the learner. Not only must learners be able to use the innovation, but its features must be focused on promoting useful outcomes that will benefit the learners. Furthermore, the learning outcomes of the future should not necessarily remain those of the past. As summarized by the noted pioneer in computer-based learning, Alfred Bork, "Memory is no longer important. Solving problems, encouraging creativity, adapting to change, and building intuition take priority" (Bork, 2000, p. 79).

If technology resources and efforts are not first-and-foremost focused on learning, it will matter very little how technically sophisticated and elegant they are. Indeed, some very thoughtful educational technology "solutions," such as Columbia's Fathom[ii] (Hane, 2003; Wilson, 2003) and the University of Illinois' Global Campus, have failed to meet their stated goal of expanding educational opportunities, most likely because they did not align with student needs and, hence, were not financially viable. The University of Illinois' launched Global Campus in January 2008 with a price tag of $8.9 million ("Hopes," 2008), but the program achieved lower enrollments and fewer available courses than had been anticipated.

In their groundbreaking article "From Teaching to Learning," Barr and Tagg asserted that "subtly but profoundly" a shift was taking place in American higher education away from the view that "A college is an institution that exists to provide instruction" to the view that "A college is an institution that exists to produce learning" (1995, p. 13). The authors readily admitted that the sort of change they were describing would require significant role and cultural changes within higher education. With specific regard to technology, they observed:

> In the Learning Paradigm, as colleges specify learning goals and focus on learning technologies, interdisciplinary (or non-disciplinary) task groups and design teams become a major operating mode. For example, faculty may form a design team to develop a learning experience in which students networked via computers learn to write about selected texts or on a particular theme.… After developing and testing its new learning module, the design team may even be able to let students proceed through it without direct faculty contact except at designated points. (p. 24)

Some colleges and universities have undergone significant transformations (in many cases as they have been compelled to by the accreditation process) from teaching-focused to learning-focused curriculum design, delivery, and evaluation processes. Corresponding changes in the way technology is used to support teaching and learning have been slower to materialize, however, perhaps because the accreditation bodies have not required such changes. Even more important is the reality that the financial and cultural incentives of educational technology support organizations at colleges and universities drive them to implement technologies that improve institutional and teaching-focused efficiencies rather than improve learning itself.

To realize Barr and Tagg's vision of a more learning-centered academy, which will help begin closing the 2-sigma gap, educators will need to be much more learning-focused in the development, implementation, and evaluation of learning technology. An important first step is to begin thinking about tools from the learner's perspective and the tasks learners perform. Accordingly, it is important to think about necessary changes in the roles of faculty and administrators as they become more focused on facilitating learning than on delivering instructional content. Additionally, more attention should be focused on technologies that help students manage their own educational careers, perhaps over long (i.e., non-traditional, disrupted) periods of time and perhaps at multiple institutions of learning.

Technology, by itself, is not the answer. Indeed, in his more recent book, *The Learning Paradigm College*, Tagg warns that technology can be used just as effectively to reinforce a teaching-centered college as it can be to foster a new learning-centered environment (2003, p. 332). Learning-centered technology implementations, he argues, should:

- focus on learning rather than teaching activities and performances;
- reinforce effective learning habits and skills (e.g. persuasive writing) taught elsewhere;
- provide ample, appropriate, and timely scaffolding during the learning process;
- deliver rapid, effective feedback on student performance; and
- facilitate and reinforce communities of "practice" or learning. (pp. 333–334)

In all of this, successful innovators will avoid limiting the influence and impact of these technologies to the boundaries of the traditional classroom. To the extent feasible, these technologies should be used to "extend the students' reach beyond a single learning environment" (2003, p. 334).

In a learner-centered model, learners are required to take greater personal responsibility for their own learning, changing the focus of education from the authority figures of education to the student as learner (Bork, 2000). For this to be possible, institutions should provide learners with tools that allow them to claim ownership and control over their own learning content and the relationships they establish in the learning process. Increasingly, learners can utilize freely available tools (e.g., blogs, social bookmarking sites, Google Docs, etc.) to create and manage their own learning experiences. This functionality enables so-called "personal learning environments" or PLEs[iii] that are becoming increasingly important features of the teaching and learning technology landscape. Teachers at all levels are likewise taking advantage of such tools that allow them to be more effective mentors, coaches, and learning facilitators. Institutions need to consider ways they can leverage such tools as they perform their unique roles as learning brokers that grant credentials and certify learner competencies.

Achieving Content and Tool Malleability Through Openness, Modularity, and Interoperability

The sort of paradigm shift described above represents change in the educational enterprise to a degree rarely seen in any human endeavor, much less in education, and especially over what needs to be a relatively short period of time. In order to sufficiently shift the focus from teaching to learning to the extent that would be required by the universal educational model practiced in developed countries today, educators will have to move into unknown and uncharted territory.

Such a shift is comparable on some level to what happened at IBM in 1980, when the company developed, produced, and distributed their first personal computer, from the decision to proceed through initial delivery, all in just over a year's time. To accomplish such a feat, the company assigned a small group of engineers to undertake the design of the system and to carry out the necessary implementation plan. Their success defied all expectations both within and without the company. At its outset, one external analyst evaluated the probability of success in such an endeavor: "IBM bringing out a personal computer would be like teaching an elephant to tap dance" ("The birth," n.d., para. 3). Some readers might find the analogy apt when thinking about the probability of getting educational institutions to fundamentally refocus their energies on student learning.

Nevertheless, building a personal computer was exactly what they did, and at a pace never before seen for other projects in the company. IBM describes the venture in these terms:

> In sum, the development team broke all the rules. They went outside the traditional boundaries of product development within IBM. They went to outside vendors for most of the parts, went to outside software developers for the operating system and application software, and acted as an independent business unit. ("The birth," n.d., para. 9)

The specific and ultimately successful implementation of the principles of modularity and interoperability in that process enabled IBM to call on outside vendors for parts for their personal computer. Their rejection of proprietary technology in favor of openness created the opportunity for IBM to call on Microsoft to develop the operating system and for a host of other companies (including Microsoft!) to go on to create thousands upon thousands of software applications, guaranteeing the long-term success of IBM's initial design. Furthermore, competing companies that chose a proprietary and closed approach for their hardware, software, or both, (e.g., Texas Instruments, Amiga, Atari, Commodore, and Radio Shack) are nowhere to be found among Twenty-First Century personal computers. Even Apple, with the initial version of their innovative Macintosh, came close to meeting disaster until they opened things up with their Macintosh II (Bush, 1996). In the end, the nature of IBM's approach not only ensured success in their initial venture, but the continued application of the same principles over the years by IBM's successors also makes it possible for today's machines to run much of the same software that was created for the original IBM PC.

Among the principles of openness, modularity, and interoperability that brought success to the IBM-PC venture, the importance of modularity seems perhaps preeminent and has been documented in detail by scholars at the Harvard Business School (Baldwin & Clark, 2000). In their initial work, they analyzed how modularity evolved as a set of design principles during the period between 1944 and 1960. Then using Holland's theory of complex adaptive systems as a theoretical foundation, they explain how the design principles they identified went on to radically transform the information technology industry from the 1960s through the end of the century. They show how modular design and design processes have fostered change in the industry as it moved from one consisting of a few dozen companies and dominated by IBM to one that involves over a thousand companies and in which IBM plays a significantly lesser role. For example, the "packaged software" sector in the information technology industry consisted of about seven firms in 1970 that were valued at just over $1 billion (as measured in constant 2002 dollars). Thirty-two years later that sector had grown to 408 companies with a market capitalization of $490 billion (Baldwin & Clark, 2006).

Unfortunately, the application of the principles that made such developments possible in the computer industry is rare to nonexistent in many areas of education today. The education technology landscape is best characterized by monolithic, enterprise technology silos with rigid, often impenetrable walls. Course management systems (CMSs), for example, are generally "all-or-nothing" propositions for institutions, teachers, and students. That is, even if you use an open source CMS like Moodle, you are (without significant customization) bound to use Moodle's content publishing tool, Moodle's quiz tool, Moodle's gradebook, etc. Moreover, the CMS paradigm itself, tied as it is to semester calendars and time-bounded learning experiences (courses), severely limits learning continuity and persistence. Teachers and students are not free to choose the right / best / preferred tool for each teaching or learning activity they undertake, thus creating a technology paradigm that artificially limits possibilities and forecloses optimal teaching and learning choices.

The monolithic and rigid nature of today's learning tools and content mirrors the way content has traditionally been made available to faculty and students—books and other resources (including online courses) have generally been all-or-nothing, take-them-or-leave-them propositions. A similar business model was prevalent in pre-Internet days, resulting in CD-ROM databases that were more expensive than many potential consumers could afford. One analysis compared this marketing approach to a public water distribution system that would require selling the whole reservoir to each household rather than placing a meter at individual homes.

New approaches to content distribution, however, particularly the OpenCourseWare (OCW) and Open Educational Resource (OER) movements, promise to make a vast array of content open to instructors and students to reuse, revise, remix, and redistribute. The OCW Consortium, beginning with MIT in 2002, has now grown to include hundreds of institutions around the world that have chosen to place course materials online.[iv] The efforts of these institutions have spawned a related effort, dubbed Open Educational Resources (OER), to make learning materials and content (as opposed to complete courses) freely available as well (Breck, 2007). Around the world, millions of people, inside and outside of academia, are publishing content under Creative Commons licensing, making that content open for others to use in a variety of ways. We are rapidly approaching the tipping point at which a critical mass of participants in open content and open learning is sufficient to exponentially increase the value of each additional participant in the network (as described in the next section).

The stunning reality of the new standard of openness is that it is quite simple. The key is to create lots and lots of open content and provide open, easy access to it. While technical standards and specifications, such as the Shareable Content Object Reference Model (SCORM), are important when it comes to producing indexing, discovering, sequencing, packaging, and tracking of content, openness by itself is a paradigm-shifting approach in the teaching and learning world. The fact that content is openly available and usable is just as important as any particular technical feature of that content.

While openness stands by itself as a radical new innovation, we need to avoid the temptation to downplay the importance of standards and specifications, for they are essential to the realization of the vision of open, modular, and interoperable learning environments. This reality is not without historical precedent. Printing became affordable and available in large part due to what we today call standards. Indeed, as one scholar declared, "This then—the standardization and rapid multiplication of texts—was what the fifteenth-century invention of printing made possible" (Bühler, 1952). Bühler also pointed out that printing's contributions went beyond the replication issue, stating that modern scholarship only became possible with the production of identical copies of texts. Although the value of mass duplication is not to be discounted, the fact that scholars could reference each other's work represented enormous value. Given this standardization, they were thus able to criticize, comment upon, connect to, and build upon what had come before. In many ways, printing standards facilitated the first widespread appearance of mashups in human history.

The existence of identical copies was but one characteristic that facilitated the eventual widespread availability of books. In addition, several other factors contributed to the production process itself, eventually increasing the opportunity for wider distribution. Characteristics such as the size of paper, the size of fonts, the number of lines per page, the viscosity and drying characteristics of ink, all worked together to make printing a viable technology. Without standard formats and formulations for each of these elements of the printing enterprise, efficient specialization and a resulting effective division of labor would not have been possible. There was no way that printers could have done their job well enough to be successful, had they been required to continue as machinist, metallurgist, and chemist.

The end result of the revolution in printing through the implementation of moveable type and associated technologies was a drastic reduction in the cost of books. In the same vein, there is little doubt that development costs for online materials are a problem. For example, one publication speculated that the president of the University of Illinois had seriously "underestimated the amount of effort it takes to create online courses" ("Hopes," 2008, para. 5) for their Global Campus project.

Parallels for standardization exist between what happened for books and what might happen with today's learning technologies and can be divided into two categories: (1) methodologies for producing the needed content, and (2) technologies for delivering and consuming the content. Success in carrying out each of these aspects of the problem depends on the availability of standard approaches to the activities of the teaching and learning enterprise as a whole.

The current state of the art for conducting each of these categories of activities in a standard way is embodied in several efforts currently underway in various quarters around the world. Some of that work involves the formulation of the concept commonly referred to as "learning objects" or "instructional" objects (Gibbons, Nelson, & Richards, 2000). The means of creating and using these learning objects in standard ways has been the goal of the Advanced Distributed Learning Initiative (ADL),[v] which seeks to "make learning accessible at anytime, anywhere in the world" (Fletcher, Tobias, & Wisher, 2007). To these ends, ADL has worked with numerous partners for about ten years in the development of SCORM, considered also to be essential for reducing life-cycle costs for online learning. Three additional and important efforts are also underway and to some extent in parallel: Common Cartridge, the Schools Interoperability Framework (SIF),[vi] and the International Federation for Learning, Education, and Training Systems Interoperability (LETSI).[vii]

SCORM, the common thread that connects each of these efforts to the others, is "a collection of standards and specifications adapted from multiple sources to provide a comprehensive suite of e-learning capabilities that enable interoperability, accessibility and reusability of Web-based learning content" ("SCORM," n.d.). The existence of 165 SCORM-conformant learning management systems in more than a dozen countries illustrates the broad and deep impact that SCORM is having in addressing interoperability problems in military, government, corporate training, higher education, and K–12 settings (Ellis, 2008).[viii]

Common Cartridge is a specification that has been formulated by the Common Cartridge Alliance[ix] in partnership with the IMS Global Learning Consortium. A group of developers representing a wide variety of organizations (several academic institutions, school districts, governmental organizations, and representatives of various commercial firms) have banded together to increase the interoperability of online learning content and tools. Rob Abel, the CEO of the IMS Global Learning Consortium, has explained (2007) that Common Cartridge does not replace SCORM, indeed it incorporates SCORM and addresses what the partners in the alliance felt were various shortcomings of SCORM as well as a very different need than SCORM. Specifically, it was "designed for online support of all forms of teaching and learning" where "SCORM was designed for self-paced computer-based training" (Abel, 2007, p. 7).

The purpose of the Schools Interoperability Framework (SIF) is to promote standards for data exchange among all educational software applications in the K–12 setting, including instructional, administrative, and infrastructure functions. SIF works on a "collaboratively defined data model" (SCORM & SIF, 2006) and implements a Web service under a Service-Oriented Architecture (Abbott, Canada, Fawcett, & Nadeau, 2008). In August 2008, the SIF Association and ADL entered into a pilot project to facilitate:

(1) passing digital content from a publisher to a learning platform;
(2) passing shareable content object (SCO) data, regardless the state, from one application to another in real-time; and
(3) providing a more comprehensive approach for interoperability within the school's environment by leveraging and utilizing SIF and SCORM data objects together (Abbott, 2008).

The work by SIF not only illustrates the complexity of the information technology problem that educators and administrators face but it also provides a model for how numerous and disparate software applications can work together to facilitate the delivery and consumption of educational content. If software can interoperate in addressing the complexities of school operation, the creation of the means for systems to work together in the design, development, and delivery of learning materials should also be possible.

SCORM, currently in Edition 3 of SCORM 2004, represents the most substantial work in this arena (Fletcher, Tobias, & Wisher, 2007). Although more changes are possible under the aegis of ADL, future substantial developments and stewardship have been delegated to LETSI. The new organization inaugurated its SCORM 2.0 efforts at a recent meeting in Pensacola, Florida. Over 60 representatives from "government, industry, military, academia, K–12 schools, and the medical community from the United States, Canada, Australia, the United Kingdom, Germany, Korea, Singapore, and Japan" (Richards, 2008, p. 1) met to discuss almost 100 white papers submitted for consideration.[x] Preparations during the run-up to the meeting in Pensacola and the sessions there established four working groups:

- Architecture
- Business Requirements
- Sequencing
- Teaching and Learning Strategies

The purpose of the LETSI effort is to take SCORM to the next level by addressing issues that the community has raised with previous versions and updating its fundamental architectures as well as to broaden stewardship for its development. The first source of potential impact on products and practice will come with the release of "a 'Design Document' for SCORM 2.0, which will basically outline what SCORM 2.0 will be" (Ellis, 2008, para.10). The final version of the specification will come later, but this first document will enable stakeholders to begin planning their future product releases. Initial developments indicate that the new version will implement Web services, the foundation of future interoperability on the Internet.

The primary difference between the objectives of LETSI and SCORM is one of focus. Where the first versions of SCORM targeted what became known as the "ilities" (Accessibility, Interoperability, Durability, and Reusability) (Bush, 2002), SCORM 2.0 will focus mainly on interoperability, as indicated by the name LETSI itself. Organizers are basing this narrowed emphasis on the supposition that the other benefits will follow naturally once interoperability is attained.

Despite its wide impact, SCORM has not been without its detractors. Some have felt that the specification was more the product of software engineers rather than instructional designers. Reaction to such concerns has been the subject of several symposia[xi] at Brigham Young University (ID+SCORM). These events have been aimed at bringing together the various disparate views on the topic (Bush, 2002). They have, in turn, raised yet additional issues.

For example, some people have believed that SCORM is only about metadata (Bush, 2002) or about the challenges of reusability (Downes, 2003). Others complain that the requirements for the size of learning objects are so vague as to make the concept meaningless, describing them as "a drop in the ocean or the ocean itself" (Bush, 2002, p. 10). This lack of definition has prompted theorists and developers to seek to better define the granularity of learning objects (Thompson & Yonekura, 2005; Wiley, Gibbons, & Recker, 2000).

A lack of understanding of SCORM and a clear understanding of its purposes are often responsible for many of the objections that are raised. For example, Romizowski has written that metadata defines the characteristics of a learning object and "facilitates its identification, classification, localization, and reutilization (defining this is what standards like SCORM are all about)" (2009, p. 57). Although the notion of metadata has often dominated information that has been distributed about SCORM, being able to describe learning objects for their ultimate distribution and reuse is but one aspect of the goals of the specification. To say that using metadata to define the characteristics of a learning object is "what standards like SCORM are all about" is like saying that card catalogs are what libraries are all about. Card catalogs and metadata are both important and contribute to the usefulness of the content to which they refer, but it is the content or its purpose that should be the focus in each case. The organizers of LETSI are hoping that their emphasis on interoperability for SCORM 2.0 will help to correct such misunderstandings.

A summary of the proceedings of the first ID+SCORM meeting at BYU along with a detailed discussion of the justification for standards appeared in a 2002 *Educational Technology* article (Bush, 2002). Reacting to this overview and the general state of SCORM, one expert stated that "in order to use a learning design with a set of objects, the learning design must specify the objects to be used, and if the objects to be used are specified, then the learning design is not reusable" (Downes, 2003, p. 1). His rejection/criticism of SCORM concluded with this observation: "Learning design and reusability are incompatible" (Downes, 2003, p. 7).

Romiszowski (2007) revisited some of Downes' comments, wondering whether SCORM would live or die. He observed that none of the presentations at the early iterations of ID+SCORM had discussed "return-on-investment or cost-benefit," given that "one of the main motivating factors for the birth of interest in design of reusable learning objects, creation of a learning objects economy, and indeed the invention of standards such as SCORM, is to rationalize the work involved in development of new courses, by avoiding unnecessary rework and the continual 'reinvention of wheels'—all this in the name of reduced costs and increased efficiency" (Romiszowski, 2007, p. 62). Reuse, he feared, could well "run aground like so many other technology-driven initiatives on the unpredictable shoals of human nature and organizational behavior" (Romiszowski, 2007, p. 62). Providing concrete examples from his own experience, he described projects that were heavily influenced by specific, local problems that caused the developers to create their own specific materials rather than rely on the materials developed in other settings.

These objections raised by Downes and by Romiszowski are not without merit. Yet there are various counterarguments to be made in both cases. Most important is the fact that just because reuse is not always possible does not mean that it is always *impossible*. In fact, although a learning object that is useful in one context, say at one institution, might be unusable in numerous other settings, it is also possible that this same learning object *could be* exactly what is needed elsewhere.

Not only is this true across numerous institutions, it might well be true across departments within the same school or university. For example, courses that provide an introduction to statistics are frequently taught in several departments on a single campus. This duplication is typically justified because the examples used by a professor in the Department of Statistics will not be the same as those used in a course taught in the Business School or in the School of Education. Nevertheless, all of these courses will contain units on statistical principles such as say, Student's t distribution, which could well have application in other courses. Why should every statistics course at a single university or on every other campus use a different learning object to present such fundamental concepts?

Reuse can exist at several levels. Although Downes (2003) argues that the reuse of instructional design is *by definition* not plausible, he would be hard pressed to argue that assets used in learning objects cannot be used in multiple settings. Whether they be maps, digital audio or video recordings of significant events, pictures, or animations, reuse at this level of granularity is not only possible but desirable.

Unfortunately, this is one area where previous and existing versions of SCORM have been lacking. Each instance of use of a particular digital asset has required that the asset be contained within a self-contained package (typically a ZIP file) for the learning object that uses the asset. The standards and specifications that follow SCORM will succeed at least partially to the extent that they can address such shortcomings.

Although SCORM is not perfect, it at least began to address the issue of establishing a framework within which learning content can be made to interoperate in a variety of settings. Just as SIF opens up the opportunity for reuse of information created and used by various operational elements of schools, SCORM still holds the promise to facilitate the sharing of learning content, not only across learning management systems but also across tools that facilitate the design and development of learning content. In addition, common authentication schemes (e.g., OpenID) built upon Web services interoperability will ultimately allow learners to seamlessly navigate multiple Web-based teaching and learning applications, opening up possibilities for personal learning environments in which multiple sources of content and experiences work together to help students learn in ways that are tailored to each individual.

With developments like SCORM 2.0 on the horizon, as well as increasingly powerful software, hardware, and networking tools, technological barriers are falling. The challenge now is to harness these new enabling technologies to create more open, modular, and interoperable learning content as well as production and learning tools that are each malleable with respect to their individual functionality. Together, these technologies will help further the transformation of education from a teaching-oriented enterprise to a learning-centered one.

The Power of the Network Effect

Creating an optimal level of content and tool malleability opens many new production contexts that in turn open various learning contexts to the benefits of the "network effect." Metcalfe's Law holds that the value of the network "is proportional to the square of the number of users of the system" *(http://en.wikipedia.org/wiki/Metcalfe's_law)*. Stated another way, value accrues to the system as a whole because the more users or "nodes" there are in a network, the more possible connections there are. As illustrated in ***Figure 1***, a network of two phones would allow only one connection from each phone to another phone, while a network of five phones allows for ten unique connections and a network with 12 phones allows for 66 connections. As the number of nodes increases, the magnitude of the network effect grows exponentially, as detailed in ***Table 1***.

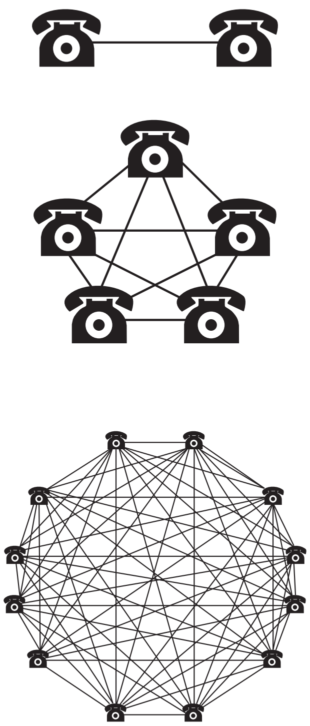

Figure 1. The Network Effect. Source: Wikipedia.

The power of the network effect is not limited to hardware-based communications networks. Metcalfe's Law is equally applicable to human networks, facilitated today more powerfully and efficiently than ever before via social networking technologies like YouTube, Wikipedia, and Flickr. With these enabling technologies, the network effect has dramatically transformed the way people interact. In *Wikinomics*, Tapscott and Williams declare that "deep changes in technology, demographics, business, the economy, and the world" have ushered in a "new age where people participate" like never before (2006, p. 10). Moreover, they contend that we have already reached a "tipping point where new forms of mass collaboration are changing how goods and services are invented, produced, marketed, and distributed on a global basis." In *The Wisdom of Crowds*, Surowiecki explains that large groups of people can be "smart" when they are diverse, individuals in the group are independent from each other, and thought processes are decentralized (2004, p. 42). Another view of so-called "crowdsourcing" suggests that humanity is now capable of "using the kind of collective intelligence once reserved for ants and bees—but now with human IQ driving the mix." What is the result? A "quantum increase in the world's ability to conceive, create, compute, and connect. We are only beginning to comprehend the consequences" (Libert, Spector, & Tapscott, 2007, p. 1).

New technologies allow virtually anyone to create and publish content globally. Even more impactful is the fact that such content creation and dissemination can be done collaboratively. Multiple people can work together to author and refine materials. Still others can annotate, tag, remix, and redistribute that content. We're no longer solely dependent upon experts and information scientists to organize and make information available to us. As millions of people create, view, and tag content, rich folksonomies (taxonomies created dynamically by large numbers of people) are created dynamically, providing future pathways to and connections between content that will benefit future learners. As more and more people engage in such activities, the network effect will grow increasingly powerful and far-reaching in its implications for teaching and learning.

The emergence of a massive, human communication network has already begun to yield significant impact on education in far-reaching ways. Awareness and understanding of these changes among practitioners and scholars, however, lags behind reality. Surprisingly, Tapscott and Williams specifically mention education only four times in their 340-page volume on "wikinomics." The references themselves are also intriguing. The first is a mention of the MIT OpenCourseWare initiative (pp. 22–23). The second references TakingITGlobal's efforts to reform education by

Table 1. The Network Effect.

Nodes	Possible Connections
1	0
2	1
5	10
12	66
50	1,225
100	4,950
1,000	499,500
10,000	49,995,000
100,000	4,999,950,000
1,000,000	499,999,500,000

providing a "set of tools and curricular activities that will get students collaborating with other students in other countries" (p. 51). The third refers to the California Department of Education's Open Source Textbook Project (p. 69). And, the fourth, an additional mention of the California textbook project (p. 301). Note that only one of these references relates to the way students actually learn—the others are about content creation and distribution.

This is additional evidence that technology's real impact on education is yet to be realized. In a 2007 IRRODL article, David Annand observed: "Much like the Industrial Revolution before it, rapid technological change in the Information Age has to date created significant, fundamental change in virtually all sectors of society *except education*" (2007, p. 6, *emphasis added*).

One of the primary reasons technology has as yet failed to transform education is the failure of educational administrators and teachers to recognize the importance of and take advantage of the network effect on teaching and learning. New social networking technologies allow large groups of teachers and learners to create, moderate, and refine learning content. Other tools allow groups of learners across the globe to interact with each other in discussions, research debates, and in the creation of new knowledge. Institutions, administrators, instructional designers, teachers, and learners should work together to explore new ways to leverage these new possibilities. For example, the California Open Source Textbook Project and broader initiatives like OCW and OER are working (and will continue to work) because they involve very large numbers of teachers and learners who are creating and improving the content.

As more and more innovative ideas are implemented to take advantage of openness and the network effect, institutions must grapple with new questions regarding "original" content creation, content ownership, content quality, content distribution and availability, etc. One of the most important developments we foresee is the reallocation of energy and attention to leveraging the potential of large-group, collaborative dialogue and learning. Beyond open- and community-source curriculum, we should continue to pursue the development of open and community learning tools. Content and tools will become increasingly effective and utilized to the extent that they are also malleable, or in other words, open, modular, and interoperable.

Conclusion

Like the man on the park bench waiting for Godot, those who watch for dramatic improvements in learning facilitated by educational technology might wonder if that which they await will ever come. After decades of watching, we are still anticipating the long-predicted transformation of teaching and learning that closes the 2-sigma gap. These changes will not be realized until teaching and learning strategies focus less on the tactical implementation of specific technologies which often simply automate the past and focus instead on the broader, transformative principles of educational technology outlined above. Namely, transformation will come when we recognize and emphasize the importance of learner-centricity, content and tool malleability, and the network effect.

The history of the book and the PC, although separated significantly in time and space, remind us of the need for increased learner-centricity in the educational enterprise. On the one hand, Gutenberg's moveable type addressed individual learner needs by making books widely available for their individual use. On the other hand, the IBM PC helped usher in the era of personal computing and with it the potential of dealing with individual differences in learning. These technologies facilitated changes in focus from teaching to learning and helped place individual learners at the center of the learning enterprise.

Technological standards and content specifications stand side by side with the ideal of openness as critically important catalysts for the long-awaited transformation of teaching and learning that Bloom and others have predicted. But they will only matter to the extent that they are bolstered by the other principles we have outlined.

Specifications and developments such as the School Interoperability Framework (SIF), SCORM, and Common Cartridge have the potential to facilitate the effective creation, packaging, deployment, and tracking of learning content and activities in ways consistent with learner needs and learner achievement. These developments will succeed as standards or specifications, however, only after we have addressed content and tool malleability issues and are committed to interoperability (i.e., enabling content and tools to be deployable in any "system" and viewable on any device). The same things can be said of openness—open access to content only matters to the extent that content is learner-centric—is created in such a way that it can be reused, revised, remixed, and redistributed in an open, interoperable technology environment.

Such an educational landscape would enable the actualization of the developments predicted in *Wikinomics*, namely a world in which massive numbers of people participate in the production, delivery, and consumption of learning content with the highest possible production values. The amount of materials that are needed for truly universal education is large enough to demand the attention of billions of producer/consumers. But the tools and the resulting content will be useful and viable only to the extent that it is learner-centric and malleable. Likewise, the network effect can only have sway if teachers and learners are able to use the content and tools created by others. And the results of student use of these tools and content must not only be connected to teachers' grade books, but they must also be available for the evaluation and improvement of the materials.

We conclude by observing that the ideal teaching and learning ecosystem would allow the use of a wide variety of tools and content for a wide variety of purposes to facilitate effective, efficient, and timely learning. Teachers and learners ought to be able to use the best tools and content to match the particular learning goals, contexts, and challenges they face. In an authentically open, modular, and interoperable environment, tools and content would be seamlessly plug-and-playable, consistent with accepted technological, usability, and accessibility standards. The realization of such ideals is essential to the creation and perpetuation of effective PLEs that hold the potential to transform the way individual learners learn.

Again, if these conditions are met—which after all is the *raison d'être* of educational technology standards, content specifications, and the OCW and OER movements—we can, perhaps, finally realize the promised synergy between technical standards and specifications, openness, content and tool malleability, and the network effect. These forces might at last combine to produce a dramatic expansion and improvement of both the quality and quantity of educational opportunities. We might never have flying cars, but maybe we can finally start closing the 2-sigma gap. □

Notes

(i) Christensen *et al.* provide a view of the public education industry "through the lenses of the theories of disruptive innovation" (p. 10). These theories are based on 20 years of research by one of the authors and a colleague at the Harvard Business School who together coined the term "disruptive technologies" (Bower & Christensen, 1995) to explain how a revolutionary technology can radically change the status quo in a particular market sector. In *Disrupting Class* the authors apply these theories to explain how changes in education are imminent and far-reaching.

(ii) Although Fathom has not achieved the financial success its founders anticipated, it apparently has gained a new lease on life and is now a repository of "free content developed for Fathom by its member institutions." See: *http://www.fathom.com/* .

(iii) See: *http://en.wikipedia.org/wiki/History_of_personal_learning_environments* .

(iv) OpenCourseWare materials are not online "courses" in the traditional sense of the term. The course materials do not generally comprise all of the materials necessary to "take a course" from beginning to end. Rather, the materials in an OCW library for any particular course represent much of the core content, frequently without the critical connective tissue added by an instructor. Assessments and assignments are also generally not included in OCW materials.

(v) The Advanced Distributed Learning Network was formed in 1999 as an operation of the US Department of Defense with the following purpose as described on its Website:

ADL employs a structured, adaptive, collaborative effort between the public and private sectors to develop the standards, tools and learning content for the learning environment of the future. The vision of the ADL Initiative is to provide access to the highest-quality learning and performance aiding that can be tailored to individual needs and delivered cost-effectively, anytime and anywhere.

See: *http://www.adlnet.gov/about/index.aspx* .

(vi) The Schools Interoperability Framework (SIF) Association explains that the SIF "ensures that data systems work together and free up educators to do what they do best: teach." See: *http://www.sifinfo.org/* . It is comprehensive and promotes the interoperation of all aspects of the K–12 information technology infrastructure (typically disparate and from numerous vendors) through a Zone Integration Server. See: *http://www.sifinfo.org/upload/presentations/C2CCBE_SIFA%20ROI%202006.ppt* . The system architecture implements a Web service through a Service-Oriented Architecture. See: *http://www.sifinfo.org/upload/presentations/89FBED_SIF_CoSN_2008.pdf* .

(vii) The International Federation for Learning, Education, and Training Systems Interoperability (LETSI) was organized by several organizations, public and private, for the development of the next generation of SCORM, SCORM 2.0. Where the initial versions of SCORM have been developed by ADL, which is supported by the US Department of Defense, LETSI brings together organizations and individuals from around the world to collaborate on what SCORM will be in the future. See: *http://www.letsi.org* . Founding members included "12 sponsors comprised of standards organizations, government programs, and suppliers, such as the Masie Learning Consortium, MedBiquitous, Adobe, Aviation Industry Computer-Based Training Committee (AICC), and Schools Interoperability Framework Association (SIFA). International organizations also are sponsoring LETSI, including Korea Institute for Electronic Commerce (KIEC) and el Instituto Latinoamericano de la Comunicación Educativa (ILCE)" (Ellis, 2008, para. 6).

(viii) Several sources provide an overview and justification of SCORM (Bush, 2002; Godwin-Jones, 2004). Other sources identify some of the challenges to working with SCORM with the limited authoring tools that are available today (Gonzalez-Barbone & Anido-Rifon, 2008).

(ix) For an overview of the mission, goals, and membership of the Common Cartridge Alliance as well as links for additional information. See: *http://www.imsglobal.org/cc/alliance.html* .

(x) SCORM 2.0 White Papers, now number over 100 and are accessible at *http://www.letsi.org/display/nextscorm/SCORM+2.0+White+Papers* .

(xi) The first two iterations of the symposia occurred in 2002 and 2003 under the name ID2SCORM. Renamed ID+SCORM, the symposia once again took place in 2007 and 2008. Most of the presentations for ID+SCORM 2008 are available in the form of PowerPoint slides with audio at: *http://arclite.byu.edu/id+scorm/index.php?title=Presentations_2008* . Depending on the speed of developments for SCORM 2.0, a reprise could once again occur in 2010.

References

Abel, R. (2007). Interoperability standards for teaching & learning using the Internet; *http://www.nacol.org/events/webinar/archive/nacol%20webinar%20slides%202007-10%20IMS.pdf* .

Abbott, J., Canada, B., Fawcett, J., & Nadeau, R. (2008). SIFA and your school district; *http://www.sifinfo.org/upload/presentations/89FBED_SIF_CoSN_2008.pdf* .

Abbott, J. (2008, August 7). The SIF Association and the Advanced Distributed Learning (ADL) officially launch SIF and SCORM pilot; *http://www.sifinfo.org/upload/press/8264CD_SIF_SCORM_Press%20Release_final.pdf* .

Annand, D. (2007). Re-organizing universities for the information age. *International Review of Research in Open and Distance Learning, 8*(3), 1–9; *http://www.irrodl.org/index.php/irrodl/article/view/372/956* .

Baldwin, C. Y., & Clark, K. B. (2000). *Design rules,volume 1: The power of modularity*. Cambridge, MA: MIT Press.

Baldwin, C. Y., & Clark, K. B. (2006). Modularity in the design of complex engineering systems. In D. Braha, A. A. Minai, & Y. Bar-Yam (Eds.), *Complex engineered systems: Science meets technology* (pp. 175–205). New York: Springer.

Barr, R. B., & Tagg, J. (1995). From teaching to learning: A new paradigm for undergraduate education. *Change, 27*(6), 13–25.

Bloom, B. S. (1984). The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4–16.

Bork, A. (2000, Jan./Feb.). Learning technology. *EDUCAUSE Review; http://net.educause.edu/ir/library/pdf/erm001g.pdf* .

Bourne, J., & Moore, J. C. (Eds.). (2003). *Elements of quality in online education: Practice and direction*. Needham, MA: The Sloan Consortium.

Bower, J. L., & Christensen, C. M. (1995, Jan./Feb.). Disruptive technologies: Catching the wave. *Harvard Business Review,* 43–53.

Breck, J. (2007, Nov./Dec.). Introduction to special issue on opening educational resources. *Educational Technology, 47*(6), 3–5.

Bright, R. L. (1967, May 30). The place of technology in educational change. *Educational Technology, 7*(10), 1–3.

Bühler, C. F. (1952). *Fifteenth century books and the twentieth century.* New York: The Golier Club.

Bunderson, C. V., & Abboud, V. C. (1971, Feb.). *A computer-assisted instruction program in the Arabic writing system* (Technical Report No. 4). Austin, TX: The University of Texas at Austin (ERIC Document Reproduction Service No. ED052603).

Bunderson, C. V., Olsen, J. B., Baillio, B., Lipson, J. I., & Fisher, K. M. (1984). Instructional effectiveness of an intelligent videodisc in biology. *Machine-Mediated Learning, 1*(2), 175–215.

Bush, M. (1989). Banquet address—CALICO '89 at the U.S. Air Force Academy. *CALICO Journal, 7*(1), 5–15; *https://www.calico.org/a-431-Banquet%20AddressCALICO%2089%20at%20the%20US%20Air%20Force%20Academy.html* .

Bush, M. D. (1996, Nov.). Fear & loathing in cyberspace: Of heroes and villains in the information age. *Multimedia Monitor; http://arclite.byu.edu/digital/heroesa5.html* .

Bush, M. D. (2002). Connecting instructional design to international standards for content reusability. *Educational Technology, 42*(6), 5–13; *http://arclite.byu.edu/digital/edtechscorm.htm* .

Christensen, C. M., Horn, M. B., & Johnson, C. W. (2008). *Disrupting class: How disruptive innovation will change the way the world learns.* New York: McGraw-Hill.

"Chuck." (2008). *Is there a flying car in your future? http://hubpages.com/hub/Is_There_a_Flying_Car_In_Your_Future* .

Computers for students. (1967, April 30). *Educational Technology, 7*(8), 19–20.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom.* Cambridge, MA: Harvard University Press.

Downes, S. (2003). Design, standards and reusability; *http://www.downes.ca/cgi-bin/page.cgi?post=54* .

Experimental high school in New York City. (1967, April 15). *Educational Technology, 7*(7), 12–13.

Ellis, R. (2008). Stewarding SCORM 2.0; *http://www.astd.org/lc/2008/0708_barr.html* .

Fletcher, J. D. (2003). Evidence for learning from technology-assisted instruction. In H. F. O'Neil, Jr., & R. Perez (Eds.), *Technology applications in education: A learning view* (pp. 79–99). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fletcher, J. D. (2008). Personal Learning Associates and the new learning environment. In J. Cohn, D. Nicholson, & D. Schmorrow (Eds.), *Integrated systems, training evaluations, and future directions* (pp. 435–443), Volume 3 of *The PSI handbook of virtual environments for training and educa-*

tion: Developments for the military and beyond. Westport, CT: Praeger Security International.

Fletcher, J. D., Tobias, S., & Wisher, R. A. (2007). Learning anytime, anywhere: Advanced distributed Learning and the changing face of education. *Educational Researcher, 36*(2), 96–102.

Gelman, D. (1991, Feb. 18). The sorrows of Werner. *Newsweek; http://www.newsweek.com/id/126603* .

Gibbons, A. S., Nelson, J., & Richards, R. (2000). The nature and origin of instructional objects. In D. A. Wiley (Ed.), *The instructional use of learning objects; http://reusability.org/read/chapters/gibbons.doc* .

Gladwell, M. (2002). *The tipping point: How little things can make a big difference*. Boston: Back Bay.

Godwin-Jones, B. (2004). Learning objects: Scorn or SCORM? *Language Learning & Technology, 8*(2), 7–12.

Gonzalez-Barbone, V., & Anido-Rifon, L. (2008, Dec.). Creating the first SCORM object. *Computers & Education, 51*(4), 1634–1647.

Graff, H. J. (1991). *The legacies of literacy: Continuities and contradictions in western culture and society*. Bloomington: Indiana University Press.

Hane, P. J. (2003, Jan. 13). Columbia University to close Fathom.com. *Information Today, Inc; http://newsbreaks.infotoday.com/nbReader.asp?ArticleId=16813* .

Harnessing innovation to support student success: Using technology to personalize education. (2008). Washington, DC: Department of Education; *http://www.ed.gov/ technology/reports/roundtable.html* .

Hopes for virtual campus collide with reality. (2008, Sept. 26). *eSchool News; http://www.eschoolnews.com/news/top-news/index.cfm?i=55358* .

Kulik, J. A., & Kulik, C. L. C. (1987, July). Review of recent research literature on computer-based instruction. *Contemporary Educational Psychology, 12*, 222–230.

Lane, M. (1980). *Books and publishers*. Lexington, MA: Lexington Books, D.C. Heath and Company.

Leonard, G. (1968). *Education and ecstasy*. New York: Delacorte Press.

Libert, B., Spector, J., & Tapscott, D. (2007). *We are smarter than me: How to unleash the power of crowds in your business*. Philadelphia: Wharton School Publishing.

Partnership for 21st Century Skills. (2007). Three K–12 leadership groups urge broad and intensive use of technology to improve education; *http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=388&Itemid=64* .

Plato. (370 B.C.). *Phaedrus; http://ebooks.adelaide.edu.au/p/plato/p71phs/phaedrus.html* .

Reeves, T. (2006). Changing how we evaluate the impact of computers in education in a flat world. Keynote Address at the Global Chinese Conference on Computers in Education, Beijing, China. Slides available at: *http://it.coe.uga.edu/~treeves/GCCCE2006KeynoteReeves.ppt* .

Richards, T. (2008). LETSI Press Release: Inaugural SCORM 2.0 workshop jump-starts LETSI; *http://www.letsi.org/download/attachments/6324770/10232008.pdf?version=1* .

Romiszowski, A. J. (2007, July/August). Topics for debate: Instructional design, learning objects, and SCORM revisited. *Educational Technology, 47*(4), 61–63.

Romiszowski, A. J. (2009, Jan./Feb.). Topics for debate: Comments on academic myths, the art of listening, reflection, and influencing others. *Educational Technology, 49*(1), 55–58.

Russell, T. L. (2008). No significant difference phenomenon; *http://www.nosignificantdifference.org/* .

Schank, R. C. (2008, June). The re-organization of schooling (video of presentation given at Brigham Young University McKay School of Education, Provo, Utah); *http://education.byu.edu/media/viewvideo.html?id=151&d=bb* .

SCORM 2004 3rd Edition. (n.d.); *http://www.adlnet.gov/scorm/index.aspx* .

SCORM & SIF – Leveraging work for successful solutions, (2006); *http://www.sifinfo.org/upload/press/289BZA_SCORM%20and%20SIF_final.pdf*.

SETDA, ISTE, & P21. (2007). Maximizing the impact: The pivotal role of technology in a 21st century education system. Report produced by the State Educational Technology Directors Association (SETDA), International Society for Technology in Education (ISTE), & Partnership for 21st Century Skills (P21); *http://www.setda.org/c/document_library/get_file?folderId=191&name=P21Book_complete.pdf* .

Something needs to be done now. (2007, Dec. 7). *eSchool News; http://www.eschoolnews.com/news/top-news/?i=50970;_hbguid=82c500e1-7421-4c66-b259472863966744* .

Stoll, C. (1999). *High-tech heretic: Why computers don't belong in the classroom and other reflections by a computer contrarian*. New York: Doubleday.

Suppes, P. (1966). The uses of computers in education. *Scientific American, 215,* 206–220; *http://suppes-corpus.stanford.edu/article.html?id=67* .

Surowiecki, J. (2004). *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies, and nations*. New York: Random House.

Symonds, W. C. (2000, Jan. 10). Industry Outlook 2000 – Services: Education. *Business Week; http://www.businessweek.com/2000/00_02/b3663149.htm* .

Tapscott, D., & A. D. Williams. (2006). *Wikinomics: How mass collaboration changes everything*. New York: Portfolio.

Tagg, J. (2003). *The learning paradigm college*. Bolton, MA.: Anker Publishing Company, Inc.

The birth of the IBM PC. (n.d.); *http://www-03.ibm.com/ibm/history/exhibits/pc25/pc25_birth.html* .

Thompson, K., & Yonekura F. (2005). Practical guidelines for learning object granularity from one higher education setting. *Interdisciplinary Journal of Knowledge and Learning Objects, 1, 163–179; http://ijklo.org/Volume1/v1p163-179Thompson.pdf* .

Wiley, D. A., Gibbons, A., & Recker, M. M. (2000). *A reformulation of learning object granularity; http://reusability.org/granularity.pdf* .

Wilson, J. M. (2003, March). Is there a future for online ed? Fathom's gone, leaving us to ask, `is anyone making money on online education?' – Viewpoint. *University Business; http://findarticles.com/p/articles/mi_m0LSH/is_/ai_98994733* .

Young, M. A. (1967, Feb. 28). What education can be like in the future. *Educational Technology, 7*(4), 1–10.