



technology, children, schools and families

The future of learning in the age of innovation

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Abstract

We are entering the innovation age. The innovation age requires very different citizens from the industrial age that dominated the globe for over a century: people who maximize their creative potential, people who not only master existing skills and knowledge, but who are capable of creating new skills and knowledge. To maximize innovation and knowledge generation, many societal factors must be in alignment - political, legal, cultural, economic. This report focuses on the critical role to be played by schools. At present, many schools (and corporate learning programmes as well) do not result in learning that supports creative behaviour, and thus are not appropriate for the innovation age. This report summarizes research on creativity, collaboration, and learning, and provides advice about how to design learning environments that result in creative learning. The report identifies a range of challenges, and six future scenarios, for teaching and learning in the age of innovation.

Keywords: creativity, innovation, learning, education, school, collaboration, knowledge, economics, learning environments

Introduction

In recent decades, many OECD member countries have undergone a transformation from an industrial to a knowledge economy (Bell, 1973; Drucker, 1993). The knowledge economy is based on "the production and distribution of knowledge and information, rather than the production and distribution of things" (Drucker, 1993, p182). Knowledge workers manipulate symbols rather than machines, and create conceptual artifacts rather than physical objects (Bereiter, 2002; Drucker, 1993; Reich, 1991). These analysts emphasize the importance of creativity, innovation, and ingenuity in the knowledge economy; some scholars now refer to today's economy as a *creative economy* (Florida, 2002; Howkins, 2001).

We are entering an age of innovation, and creativity will grow in importance due to several broad societal and economic trends:

1. Increasingly globalized markets result in greater competitiveness, even for industries that historically had been protected from significant challenge
2. Increasingly sophisticated information and communication technologies result in shorter product development cycles, increasing the pace of innovation and change
3. Increasingly sophisticated information technology is spreading the scope of automation into sectors of the economy that formerly required active human involvement, including increasingly advanced service and knowledge work, thus obsoleting those job categories that do not involve active, daily creativity
4. Global labor market competition has resulted in low-skill, low-creativity jobs moving to extremely low-wage countries such that OECD labor forces can no longer compete
5. Increasing wealth and leisure time in OECD countries (and beyond) have increased the demand for the products of the creative industries. As of 2007, the creative industries represented over 11% of U.S. GDP (Gantchev, 2007).

These trends result in regional, economic, and organizational shifts - such as flexible specialization, regional economies structured around a loose network of small producers, and short product runs - that place creativity at a premium (Jeffcutt and Pratt, 2002, p. 226).

An economic school of thought known as *new growth theory* argues that creativity and idea generation are central to today's economy; the driver of economic growth is technological change (Cortright, 2001; Lucas, 1988; Romer, 1990; Solow, 1956, 1994). In this view, knowledge is an intrinsic part of the economic system - a third factor, added to the traditional two of labor and capital (Florida, 2002; Romer, 1990). Peters and Humes (2003) noted that "economic progress and expansion has always depended on new ideas and innovation ... What has changed, perhaps, is that knowledge is now recognized as being at least as important as capital (physical and financial)" (p1). New growth theory implies that those nations that thrive will be the ones that succeed at innovation - generating and applying new knowledge.

The creative industries have been defined by the UK Department of Culture, Media, and Sport (DCMS) as "those activities which have their origin in individual creativity, skill and talent and which have a potential for wealth and job creation through the generation and exploitation of intellectual property" (DCMS, 1998); these sectors include advertising, designer fashion, film, video-games, and architecture and art. In the UK, national policy since the late 1990s has emphasized the creative industries as part of a broader strategy of becoming a "competitive knowledge economy" (DTI, 1999; NACCCE, 1999).

However, new growth theory suggests that all industries today necessarily involve creativity (eg Jefcutt and Pratt, 2002). In the age of innovation, creativity is of concern not only for economic sectors traditionally thought to involve creativity. OECD nations have responded by developing national policies "for encouraging knowledge generation, knowledge acquisition, knowledge diffusion, and the exploitation of knowledge" in science, research, and education (Peters and Humes, 2003, p2). Concrete efforts fall into two broad categories: enhancing the knowledge-generating potential of society, and reforming educational institutions to deliver learning that supports creative work.

To enhance the knowledge-generating potential of society, countries focus on the identification of institutional, societal, and communication structures that foster the diffusion and exploitation of knowledge. Organizational systems that foster retention and dissemination of knowledge are referred to as *knowledge management systems*.

National systems that foster retention and dissemination of knowledge include infrastructure efforts that bring people together - transportation and communication networks.

To deliver learning that supports creative work - through schools and also in lifelong learning - national governments have focused on educational institutions. How might such institutions be reformed to most effectively foster learning for creativity? Information delivery is not enough - educational institutions need to prepare individuals to generate *new* knowledge. And because knowledge grows and changes so rapidly, learning must continue through the lifespan. The educational system must expand beyond compulsory formal schooling.

Since the first OECD report on the knowledge economy in 1996, the OECD played a leading role in exploring the implications of this shift:

OECD analysis is increasingly directed to understanding the dynamics of the knowledge-based economy and its relationship to traditional economics, as reflected in '*new growth theory*'. The growing codification of knowledge and its transmission through communications and computer networks has led to the emerging 'information society'. The need for workers to acquire a range of skills and to continuously adapt these skills underlies the '*learning economy*'. The importance of knowledge and technology diffusion requires better understanding of knowledge networks and '*national innovation systems*'. (OECD, 1996; emphasis in original)

In the years following this prescient report, OECD's CERI project generated a series of reports about the implications of this historic shift for educational institutions (OECD, 2000, 2001, 2003, 2004).

In the first half of this report, I present a brief summary of recent research on creativity, collaboration, and learning, to provide an important background to the task of envisioning possible futures. I then identify five factors that shape a multi-dimensional space of possible futures: technology, customization of learning, diffusion of learning, organizational learning and innovation, and the role of educational professionals. Then I draw on recent research and these five factors to elaborate on six scenarios that were first presented in *What Schools for the Future?* (OECD, 2001).

Broadening our conceptions of creativity

Psychological research on creativity—from the 1960s focus on personality, through the 1970s and 1980s focus on cognition—have been limited to creative outputs that are highly valued in the West: fine art painting, basic science, and symphonic compositions. As a result, the exceptional creators that have been studied have been those who have excelled in one of these traditional European genres. In his 1993 book *Creating Minds*, Howard Gardner discussed seven exemplary creators: Freud, Einstein, Picasso, Stravinsky, (T.S.) Eliot, (Martha) Graham, and Gandhi. In his 1996 book *Creativity*, Mihaly Csikszentmihalyi interviewed 100 exceptional creators, almost all of whom attained their eminence through science or the fine arts.

These forms of creativity will play an important role in the creative societies of the future. But from an education and policy making perspective, these forms are unlikely to provide leverage for increasing the overall creativity of a society and an economy; specifically, they represent a small fraction of the overall revenues accruing to the creative industries. Pratt (2004) has argued that the term "creative industries" implies an individualistic view, such that artsy types are the "creatives" and others are not; thus he prefers the term "cultural industries". The focus on fine art painting has resulted in a neglect of filmmaking, graphic arts (including website design), and animation (including video-games). The focus on basic science has resulted in a neglect of applied science,

engineering, and technology, the source of many financially successful innovations. The focus on art music has resulted in a neglect of improvisational performance, of rock bands, of electronica, and music videos - all of which have substantially broader societal dissemination as well as larger economic impacts.

The traditional response has been to argue that high art forms represent the purest essence of the human creative impulse, and that these "lower" forms are made less pure by their revenue-generating potential. But this traditional response is almost impossible to defend any more, when artists themselves have been increasingly challenging this hierarchy and these divisions. In the 1960s, pop artists like Andy Warhol and Roy Lichtenstein broke the boundaries between high and low art, incorporating elements of advertising graphics and comic strips into their paintings. The Fluxus group began experimenting with performance and installation art, and in the following decades, installation art has become increasingly dominant within the mainstream art world. In the 1970s, the New Hollywood era in film was a major creative break in movie production. In the 1980s, the advent of MTV and its music videos enabled a new burst of creativity among dance choreographers and film artists. Any serious treatment of creativity in the early years of the 21st century must consider the full range of human innovation. A complete explanation of creativity must also explain comic strips, animated cartoons, movies, music videos, mathematical theory, experimental laboratory science, the improvised performances of jazz and rock music, and the broad range of performance genres found in the world's cultures (Sawyer, 2006c).

A focus on European high art forms implicitly privileges a set of values that is culturally and historically specific - at a time when innovation economies are found around the globe. In recent years, scholars in fields such as anthropology and sociology have examined the nature of creative genres in non-Western cultures, and have found that most of these non-Western genres are very different from European high art forms (Becker, 1982; Layton, 1991; Sawyer, 2006c). For example, many non-Western cultures have different conceptions of the individual and of creative activity that lead them to downplay the degree of originality in their works, and to emphasize their continuity with tradition (whereas in Western cultures, creators generally call attention to the originality in their works and emphasize how they break with tradition). A complete explanation of the global shift to an innovation economy requires a profound exploration of the broad range of human creative expression.

The increasing importance of collaborative creativity

Most studies of creativity have been conducted by psychologists. This research tends to focus on cognitive processes during and leading up to the moment of insight (eg Ward, Finke and Smith, 1995). This moment almost always occurs when the individual is alone, in isolation; as the peak experience in creative lives, its salience fascinates us and calls out for study. As a result, many creativity researchers have focused on the moment of creative insight, and attempted to analyze it as a psychological or cognitive process.

However, close studies of how creativity occurs in the real world reveals that the mythical moment of insight is misleading. The innovations that impact our world rarely emerge, fully formed, from a single moment of insight. Rather, they typically involve many small "mini-insights," perhaps one or more each day; and the primary work of the creator is to bring those serial insights together over time, to result in effective innovation. Here are two typical reports from exceptionally creative individuals:

Literary critic Wayne Booth: "My creative periods tend to be sort of spread out rather than moments of actually clear illumination....generally speaking, it's a matter of hard work and steady progress rather than moments of total transformation and clarity." (in Csikszentmihalyi and Sawyer, 1995, p357)

Sculptor Nina Holton: "You have these ideas, and then you work on them. As you work on them, you get new ideas....One makes the other one come out." (in Csikszentmihalyi and Sawyer, 1995, p353)

This requires conscious expertise on the part of the creator - to structure the work day so that these mini-insights continue to emerge, to implement systems and practices to enable each insight to spark the next, and to enable the aggregation of multiple insights to result in the eventual emergence of a worthwhile idea.

These mini insights are deeply embedded in a broader social process (Csikszentmihalyi and Sawyer, 1995). The periods of hard work which precede and follow the insight are fundamentally social, deeply rooted in the social group of colleagues and in the individual's internalized understanding of the creative domain itself. The balance of hard work and idle time which emerges from these interviews can also be viewed as a balance between social interaction and individual isolation. As Csikszentmihalyi and Sawyer (1995) wrote, based on an interview study with 60 exceptional creators:

we found that creative individuals had a strong subjective awareness of external social or discipline influences at each creative stage. When asked to describe a moment of creative insight, they typically provided extended narratives that described not just a single moment but a complex, multi-stage process, with frequent discussions of interpersonal contact, strategic or political considerations, and awareness of the paradigm, of what questions were interesting as defined by the discipline The moment of creative insight ... is surrounded and contextualized within an ongoing experience that is fundamentally social. (p334)

A psychological focus on the individual is contradicted by the empirical record in a second, more important, way: in the great majority of innovations throughout history, the small insights that eventually led to the innovation each were generated by different individuals. This research is consistent with sociological approaches such as the *production of culture* perspective (Peterson and Anand, 2004), as described by Pratt (2004):

The value of this perspective is that it seeks to present cultural outputs as the result of collective innovation by a number of participants whose participation is various, but linked together by the organization of production. Thus, it directs our attention to the analysis of complex organizational forms, as well as individual positioning within them, that constitute particular cultural forms. Production in this sense is not only suggestive of creative and innovative ideas, but also of the conditions under which these ideas may be mobilized (p118).

Innovations emerge from complex social systems, with constant communication, collaboration, and knowledge sharing, to accomplish the necessary process of enabling ideas to spark later ideas, and to enable a social process whereby the multiple component insights could be brought together appropriately to generate an effective innovation.

Collaboration in social networks accelerates innovation because more individuals can have more ideas. The challenge, of course, is to design effective organizational systems so that ideas build on each other, rather than opposing and canceling each other out; so that ideas accumulate over time to result in the emergence of creativity, rather than deteriorating in a political morass of failed projects.

In today's economy, the most important forms of creativity - movies, television shows, big science experiments, music videos, compact disks, computer software, video-games - are joint cooperative activities of complex networks of skilled individuals. The creative products that US society, for example, is best known for today - including movies, music

videos, and video-games - are all made by organized groups of highly specialized individuals.

In today's creative society, even creative genres that have traditionally been associated with solitary individuals are reshaping around collaboration. For example, writing seems a uniquely solitary activity; however, much creative writing today is deeply collaborative. The scripts of all movies and television shows are created by teams of writers, each contributing throughout the process (Sawyer, in press). The internet has enabled new forms of collaborative writing. The best known is the wiki: a web page that anyone may modify at any time, such as the online encyclopedia Wikipedia. Also well known is the community of bloggers, known as the blogosphere; this likewise represents a collective social phenomenon. Most bloggers provide links to other bloggers who write on the same topic, and frequently reference each other's postings in their own.

Some writers have begun to form writers' collaboratives - groups of writers who work together to author a single text, which is then published under the name of the collaborative and not any individual author. Two online writer communities that I turned up with an October 2008 internet search were Protagonize (www.protagonize.com) and StoryMash (www.storymash.com).

Various information technologies, including the internet, have enabled new forms of collaboration such as *mash-ups* and *modding*. A "mash-up" is a new combination of two existing products; it can refer to music or video sampling, but more commonly refers to web applications that combine data from more than one source. The Google Maps application supports mash-ups by allowing its mapping data to be used on other sites; for example, the WikiCrimes web site combines this map data with user postings of crime locations (<http://www.wikicrimes.com>). Mash-up sites often support broad collaboration by allowing all users to contribute; any user of WikiCrimes can mark the location of a crime.

"Modding" occurs when a user of a product modifies the product to better suit his or her needs. Modding is particularly common in strong user communities, where users collaborate to share their new modifications. Many examples of modding are found in extreme sports. As an example of modding, extreme bike jumpers often lift their feet off the pedals while in mid-air. This results in a problem: the bike pedals spin around during this time, making it difficult for the biker to get his feet positioned back on the pedals again at the end of the maneuver. One bike jumper modified the pedals to address this problem by inserting a small circle of foam padding on the pedal axle next to the pedal, thus preventing the pedals from spinning in midair but still allowing the pedals to be used when on the ground (Luthje, Herstatt and von Hippel, 2002). Many examples of modding are also found in software; dedicated video-gamers often reverse-engineer and modify their game's program. An example is the widespread modding of the LEGO Mindstorms robotic control system (Koerner, 2006).

Theorizing collaboration

To explain the creativity of complex collaborating groups, we need a theoretical framework that allows us to understand how groups of people work together, and how the collective actions of many people result in a final created product. These forms of creative production involve *distributed cognition*—when each member of the team contributes an essential piece of the solution, and these individual components are all integrated together to form the collective product. Most of today's important creative products are too large and complex to be generated by a single individual; they require a team or an entire company, with a division of labor and a careful integration of many specialized creative workers.

In the 1980s and 1990s, cognitive science underwent an important shift away from a focus on isolated individuals, toward a *situated* view of knowledge (Greeno, 2006;

Robbins and Aydede, 2008). Cognitive scientists were deeply influenced by several strands of research including the ethno-methodological focus on meaning-making found in studies of situated cognition (eg Suchman, 1987); Hutchins' (1995) work on collective cognition; and activity theory, practice theory, and sociocultural theory, based in American pragmatism and in the Soviet psychology of Vygotsky (as in works by M. Cole, B. Rogoff, and J. Wertsch). These studies documented many complex activities in which individuals participate as but one component in a distributed socio-technical system. Many of these studies take an anthropological approach to the study of task-focused work teams, and these studies have helped scholars to better understand how individuals and technological artifacts function in complex systems of activity. Such studies include the Lancaster study of air traffic control (Dourish, pp64-68) and collaborative virtual environments like DIVE and MASSIVE (Dourish, pp88-91). These studies demonstrate that social action is embedded, that social order emerges from practice, and that individuals and technological artifacts are unavoidably "embedded in a set of social and cultural practices" (Dourish, 2001, p97).

The concept of situated cognition is closely related to the concepts of *embodiment* and *mutualism* (Prinz, 2008). "Embodiment" is the notion that before computers can be truly intelligent they must move out into the world and become "embodied" in moving, acting robotic devices (Clark, 1997). Embodiment is central to Dourish's (2001) discussion of what he calls *tangible computing*, a term meant to encompass Norman's "invisible computing" and Weiser's "ubiquitous computing." For Dourish (2001), embodiment "means being grounded in everyday, mundane experience" (p125) and is "the property of our engagement with the world that allows us to make it meaningful" (p126).

"Mutualism" is the position that mind cannot be separated from the physical and biological world (Still and Costall, 1991). Mutualism shares with situated cognition a desire to avoid reductionism to any one explanatory factor - whether the physical brain (contrasted with the mental), or the individual mind (contrasted with the sociotechnical system). Mutualism shares an interest in exploring holistic phenomena that emerge from processes of complexity. As Pickering writes, "mutualism aims for emergence without mystery" - it rejects reductionist explanation of complex systems, but without arguing for any spooky non-material forces (Pickering, n.d.). Thus, the mental cannot be reduced to physical causes. Pickering allies this position with critiques of cognitivism including the embodiment tradition starting with Winograd and Flores (1986) and with connectionism (Bechtel and Abrahamsen, 1991).

Among education researchers, these theoretical approaches have been broadly influential, leading to what I call a *sociocultural* approach (Sawyer, 2005). Within socioculturalism, I include cultural psychologists, Vygotskian educational theorists, and those studying situated action in learning environments (Cole, 1996; Forman, Minick and Stone 1993; Greeno and Sawyer, 2008; Lave and Wenger, 1991; Rogoff, 1990; Suchman, 1987; Valsiner, 1998; Wertsch, 1998). This is a broad definition, because each of these areas holds to subtly different theoretical positions; but they can be grouped for our purposes because they generally hold to a view that the individual and the social are inseparable; the education researcher cannot meaningfully distinguish between what is internal to the individual and what is external context. As the prominent sociocultural psychologist Barbara Rogoff (1990) has argued, "The child and the social world are mutually involved to an extent that precludes regarding them as independently definable" (p28).

Sociocultural approaches are broadly compatible with two prominent traditions in the study of collaboration and learning: First, researchers working within a Piagetian socio-cognitive framework have emphasized the mediating role played by conflict and controversy (Bearison, Magzamen and Filardo, 1986; Doise and Mugny, 1984; Miller, 1987; Perret-Clermont, 1980); second, researchers working within a Vygotskian framework have emphasized how participants build on each other's ideas to jointly construct a new understanding that none of the participants had prior to the encounter (Forman, 1992; Forman and Cazden, 1985; Palincsar, 1998).

The learning sciences

Soon after the turn of the century, education researchers began to publish books and reports exploring the implications for formal schools of the transition to the age of innovation (eg Bereiter, 2002; Hargreaves, 2003; Sawyer, 2006b). As this transformation continues in the future, knowledge and learning will become increasingly important. For career success, each individual worker will be expected to know a great deal more, and to continually learn to adapt to a changing technological and competitive environment. However, this knowledge must be of a type that can support creative work. The field that studies how different forms of knowledge align with different forms of learning is called *the learning sciences* (Sawyer, 2006a). Learning sciences is an interdisciplinary field that studies teaching and learning. The learning sciences has been deeply influenced by the above shifts in cognitive science, away from a focus on individual mental representations and processes, toward distributed cognition, situativity, and embodiment. Learning scientists study learning in a variety of settings - not only the more formal learning of school classrooms, but also the more informal learning that takes place at home, on the job, and among peers. The goal of the learning sciences is to better understand the cognitive and social processes that result in the most effective learning, and to use this knowledge to redesign classrooms and other learning environments so that people learn more deeply and more effectively. The sciences of learning include cognitive science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, instructional design, and other fields. In the remainder of this report, I draw on learning sciences findings to identify a set of recommendations for how societies can respond to key trends through 2025 and beyond.

Sawyer (2006d) has argued that schools cannot effectively respond to the shift to a knowledge-based creative economy without first moving beyond widely held assumptions about schooling that include the following:

- *Conception of knowledge.* Knowledge is a collection of facts and procedures.
- *Conception of schooling.* The goal of schooling is to transfer facts and procedures into students' heads.
- *Conception of the teacher.* The teacher is the individual who possesses these facts and procedures, and whose mission is to transfer them to students.
- *Conception of curriculum.* Simpler facts and procedures are to be transferred first; later facts and procedures progressively build on top of these simpler ones.
- *Conception of assessment.* The success of schooling can be determined by administering paper-and-pencil tests that determine how many of these facts and procedures the student has internalized.

Collectively, this set of traditional assumptions has been called, variously, a *transmission and acquisition* model (Rogoff, 1997), the *banking metaphor* (Freire, 1989), *instructionism* (Papert, 1993), and *the standard model* (OECD, 2008).

The problem is that this standard model was designed for the industrialized economy of the early 20th century. Although schools based on this model have been effective at transmitting a standard body of facts and procedures to students, they are not able to support students in mastering the kinds of knowledge required for creative work. But the structural configurations of today's schools make it very hard to create learning environments that result in deeper understanding. One of the central underlying themes of the learning sciences is that students learn deeper knowledge when they engage in activities that are similar to the everyday activities of professionals who work in a discipline. This focus on *authentic practice* is based on a new conception of the expert

knowledge that underlies knowledge work in today's economy. In the 1980s and 1990s, scientists began to study science itself, and they began to discover that newcomers become members of a discipline by learning how to participate in all of the practices that are central to professional life in that discipline. And increasingly, cutting-edge work in the sciences is done at the boundaries of disciplines; for this reason, students need to learn the underlying models, mechanisms, and practices that apply across many scientific disciplines, rather than learning in the disconnected units that are found in many standard model science classrooms.

I have argued (Sawyer, 2008) that learning environments that prepare learners for the knowledge economy will look very different from this standard model. Key characteristics include the following:

Deeper conceptual understanding. Rather than simple accumulation of facts and skills, learners construct deeper conceptual understanding and the ability to think and problem solve with their knowledge.

Availability of diverse knowledge sources. Learners can acquire knowledge whenever they need it from a variety of sources: books, websites, and experts around the globe.

Collaborative group learning. Students learn together as they work collaboratively on authentic, inquiry-oriented projects.

Assessment for deeper understanding. Tests should evaluate the student's deeper conceptual understanding, the extent to which their knowledge is integrated, coherent, and contextualized.

I elaborate each of these characteristics in the four following sections.

Deeper conceptual understanding

By the 1980s, cognitive scientists had discovered that children retain material better, and are able to generalize it to a broader range of contexts, when they learn deep knowledge rather than surface knowledge, and when they learn how to use that knowledge in real-world social and practical settings. In the late 1980s, these learning scientists began to argue that standard model schools were not aligned with the knowledge economy.

Studies of knowledge workers show that they almost always apply their expertise in complex social settings, with a wide array of technologically advanced tools along with old-fashioned pencil, paper, chalk, and blackboards. These observations led many cognitive scientists to a *situated* view of knowledge, as described above, and learning sciences researchers have adopted this situated view (Greeno, 2006). "Situated" means that knowledge is not just a static mental structure inside the learner's head; instead, knowing is a process that involves the person, the tools and other people in the environment, and the activities in which that knowledge is being applied. This perspective moves beyond a transmission and acquisition conception of learning that is implicit in the standard model; in addition to acquiring content, what happens during learning is that patterns of participation in collaborative activity change over time (Rogoff, 1990).

In the knowledge economy, memorization of facts and procedures is not enough for success. Educated graduates need a deep conceptual understanding of complex concepts, and the ability to work with them to generate new ideas, new theories, new products, and new knowledge - through complex cognitive operations such as conceptual elaboration and conceptual combination. They need to be able to critically evaluate what they read, to be able to express themselves clearly both verbally and in writing, and to be able to understand scientific and mathematical thinking. They need to learn integrated and usable knowledge, rather than the sets of compartmentalized and decontextualized facts emphasized by instructionism. They need to be able to take

responsibility for their own continuing, life-long learning. These abilities are important to the economy, to the continued success of participatory democracy, and to living a fulfilling, meaningful life. The standard model of schooling is particularly ill-suited to the education of creative professionals who can develop new knowledge and continually further their own understanding.

Diverse knowledge sources

In the standard model, the teacher is assumed to possess all of the knowledge. In the type of learning suggested by learning sciences research (for example, scaffolded constructivist activities such as inquiry- and project-based learning) students gain expertise from a variety of sources - from the internet, at the library, or through email exchange with a working professional - and the teacher will no longer be the only source of expertise in the classroom. Learners will acquire knowledge from diverse sources; of course, expert support from the teacher can facilitate these learning processes, but the teacher's involvement will not be one of transmitting knowledge.

Collaboration

In the first part of this report, I emphasized the increasing importance of collaboration, both in creativity and in learning. In addition to this body of research supporting the educational benefits of collaboration, the innovation economy demands graduates who are highly skilled at creating together in groups (Sawyer, 2007). But in standard model schools, there is a belief that a student only knows something when that student can do it on his or her own, without any use of outside resources. There is a mismatch between the standard model and the situated, collaborative knowledge and practice that I described above.

Assessment

David Guile (2003) has explored the implications of the knowledge economy for educational institutions and for the policy debate. He begins with the concept of "credentialism" (Young, 1998), one possible response to the shift to the knowledge economy. Credentialism is the belief that education is about the acquisition of pre-existing knowledge; the goal of educational institutions should be to ensure that "the vast majority of the population achieve qualifications or certified skills and knowledge that relate to their future employment" (Guile, 2003, p92). Learning is conceived of as the acquisition of certified knowledge and skills, and lifelong learning is conceived of as a continuing accumulation of qualifications.

Guile goes on to point out that this conception of knowledge and learning is inadequate - mastering existing knowledge and skills is not sufficient to generate the new knowledge that the innovation economy requires. First, credentialism assumes that knowledge and skills are decontextualized commodities to be acquired; when in fact, in knowledge-intensive workplaces knowledge is situated - embedded in contexts and social practices (Greeno and Sawyer, 2008; Lave and Wenger, 1991). Furthermore, the key need is for workers who are capable of continuing innovation, and the certifications granted by today's educational institutions provide no measure of that capability (Guile and Fonda, 1999; Young, 1998).

The danger is that policy makers could attempt to address the educational needs of the creative society by providing credentialist solutions. In fact, this has been the primary form of response in the UK and the EU (Guile, 2003), and the United States, with the 2001 passage of the No Child Left Behind legislation, with its core focus on standardized test measures.

As I argue below, the schools of the future will increasingly result in customized learning. Yet today's assessments require that every student learn the same thing at the same time. The standards movement and the resulting high-stakes testing are increasing standardization, at the same time that learning sciences and technology are making it possible for individual students to have customized learning experiences. Customization combined with diverse knowledge sources enable students to learn different things.

Schools will still need to measure learning for accountability purposes, but we don't yet know how to reconcile accountability with customized learning.

In today's high-stakes testing environment, learning sciences researchers need to demonstrate that their methods result in better student outcomes (Pellegrino, Chudowsky and Glaser, 2001). Today's standardized tests assess relatively superficial knowledge and do not assess the deep knowledge required by the knowledge society. Standardized tests, almost by their very nature, evaluate decontextualized and compartmentalized knowledge. For example, mathematics tests do not assess model-based reasoning (Lehrer and Schauble, 2006); science tests do not assess whether pre-existing misconceptions have indeed been left behind (diSessa, 2006; Linn, 2006) nor do they assess problem-solving or inquiry skills (Krajcik and Blumenfeld, 2006). As long as schools are evaluated on how well their students do on such tests, it will be difficult for them to leave the standard model behind.

One of the key issues moving forward is how to design new kinds of assessment that correspond to the deep knowledge required in today's knowledge society (Carver, 2006; Means, 2006). Several learning sciences researchers are developing new assessments that focus on deeper conceptual understanding.

In classrooms that make day-to-day use of computer software, installed on each student's own personal computer, there is an interesting new opportunity for assessment—the assessment could be built into the software itself. After all, the learning sciences has found that effective educational software has to closely track the students' developing knowledge structures to be effective; since that tracking is being done anyway, it would be a rather straightforward extension to make summary versions of it available to teachers. New learning sciences software is exploring how to track deep learning during the learning process, in some cases inferring student learning from such subtle cues as where the learner moves and clicks the mouse—providing an opportunity for assessment during the learning itself, not in a separate multiple-choice quiz (eg Gobert, Buckley and Dede, 2005).

Five factors impacting the future of learning

As the age of innovation unfolds over the coming decades, and societies, organizations, and educational institutions evolve, the following unresolved challenges must be addressed. How these challenges are resolved will in large part determine which future scenario of learning will emerge.

1. Technology

For decades, educational futurists have been claiming that computers will change schools. The first was in the 1950s, when B.F. Skinner claimed that his "teaching machines" made the teacher "out of date" (1954, 1968, p22). Then, Papert's 1980 book *Mindstorms* argued that giving every child a computer would allow students to actively construct their own learning, leaving teachers with an uncertain role: "schools as we know them today will have no place in the future" (p9). The rise of the internet in the 1990s resulted in an increasing belief that ICT would soon transform schools. However, despite decades of rapid growth in the capabilities of ICT, and substantial government funding to install computers and high-speed internet connections into schools, there is almost no evidence that ICT has enhanced learning (Cuban, 2001). Furthermore, research suggests that when ICT are introduced to schools, they are embedded into existing standard model practices, rather than used to drive a fundamental transformation of schooling. For example, many textbook publishers today are convinced that within a few years, paper textbooks will be replaced by laptop computers that store all of a student's textbooks and curriculum materials. But if every student has a laptop that contains the same textbooks as before, nothing fundamental has changed.

So it is important to make a distinction between ICT that sustains the existing standard model, and ICT that transforms the standard model towards a more learning-sciences

based learning environment. Learning scientists are exploring technologies that support the authentic, situated, and collaborative essence of creative learning (see Sawyer, 2006a). One example is the increasing use of inexpensive wireless interactive learning devices (WILD), handheld computers that are networked and capable of communicating with each other. WILD include personal digital assistants (PDAs) such as the Palm Pilot, and also, increasingly, mobile phones. The promise of harnessing computing where every student has his or her own computer, and where they are available everyday, anytime, anywhere for equitable, personal, effective, and engaging learning give WILD a greater transformative potential than desktop computers. As of 2006, more than 10% of US schools provided handhelds to students (Pea and Maldonado, 2006). The popularity of handhelds reflects the desire of schools to make computing integral to the curriculum, rather than only occasionally used in labs. As of 2005, 55% percent of U.S. children between the ages of 8 and 18 owned a handheld videogame player (Pea and Maldonado, 2006). Since that report, a new generation of handheld devices has become available that have internet capabilities, such as the Nintendo DS and the iPhone 3G, and similar devices raise the level of internet sophistication even higher. At present, there is almost no educational software available for these platforms, but the potential is enormous. One promising current effort is the European Union's m-Learning project (www.m-learning.org). The m-Learning project is aimed at young adults, aged 16-24, who are most at risk of social exclusion, and the project's goal is to develop new products and services that will deliver learning experiences via inexpensive, portable devices that are accessible to almost everyone, primarily, mobile phones.

The potential is that this technology could support a form of technology use that is embedded in the ongoing situated practice of the learning community. The 2004 FutureLab report *Literature Review in Mobile Technologies and Learning* (Naismith, Lonsdale, Vavoula and Sharples, 2004) emphasizes the alignment between the affordances of WILD and the key principles emerging from learning sciences research. First, WILD enable learners to actively construct their own knowledge, for example through *participatory simulations* such as the Virus Game (Collella, 2000), where learners play the role of hosts in the spread of a virus, and their WILD keep track of who they meet and how the virus spreads. Second, WILD support situated activities that are embedded in authentic contexts, such as MOBIlearn (Lonsdale et al, 2003), a major European research project that is focused on context-aware delivery of content and services, using location-sensitive technologies such as GPS. Third, WILD support collaborative learning environments, both because the devices are networked, and also because they are small enough to be used while learners are engaged in face-to-face activities. An example is the MCSCL project in Chile (Zurita and Nussbaum, 2004), which is using hand-held computers to encourage face-to-face collaboration.

In addition to the potential classroom applications, WILD also enable anytime, anywhere learning, because students can interact with learning content outside of the classroom. Educational software companies have the opportunity to provide small pieces of educational content that students can access while they are engaged in a different activity: watching television or waiting for the bus.

The addition of GPS capabilities to these devices provides for another potential opportunity: context and location sensitive learning software. Several projects are exploring educational applications that respond to the wearer's current location, such as *tour guides* (Abowd et al, 1997) and *location-aware language learning applications* that adapt the content presented according to users' location (Ogata and Yano, 2005), and *digitally augmented field trips* (Rogers et al, 2004; Williams et al, 2005). Handhelds are becoming particularly widespread in informal learning settings such as science centers and other museums.

Because learners are networked together as they use WILD, it is an example of *computer support collaborative learning (CSCL)*, a burgeoning research area with international conferences every alternate year. The acronym MCSCL is sometimes used to refer to Mobile CSCL. These applications are usually internet-based and often rely on

desktop computers as well as wireless devices. Even when based on desktop computers, CSCL applications share many of the same benefits: they enable collaborative, authentic learning that extends beyond the boundaries of the classroom.

The key to avoiding the mistakes of past advocates of learning technology is to realize that computers will never attain their full potential if they are merely add-ons to the existing standard model classroom. Appropriate use of information technology requires a fundamental rethinking of the entire learning environment.

2. Customization

The goals of standard model schools were to ensure standardization - all students were to memorize and master the same core curriculum - and this model has been reasonably effective at accomplishing these goals. Standard model schools were structured, scheduled, and regimented in a fashion that was explicitly designed by analogy with the industrial-age factory (Callahan, 1962), and this structural alignment facilitated the ease of transition from school student to factory worker.

In the standard model, everyone learns the same thing at the same time. Many parallel structures and processes of these schools align to enforce standardization. But learning sciences findings suggest that each student learns best when they are placed in a learning environment that is sensitive to their pre-existing cognitive structures; and learning sciences research has shown that different learners enter the classroom with different structures. Learning sciences research suggests that more effective learning will occur if each learner receives a customized learning experience.

Educational software gives us the opportunity to provide a customized learning experience to each student to a degree not possible when one teacher is responsible for six classrooms of 25 students each. Well-designed software could sense each learner's unique learning style and developmental level, and tailor the presentation of material appropriately (see Koedinger and Corbett, 2006, for an example). Some students could take longer to master a subject, while others would be faster, because the computer can provide information to each student at his or her own pace. And each student could learn each subject at different rates; for example, learning what we think of today as "5th grade" reading and "3rd grade" math at the same time. In age-graded classrooms this would be impossible, but in alternative models of schooling there may be no educational need to age-grade classrooms, no need to hold back the more advanced children or to leave behind those who need more help, and no reason for a child to learn all subjects at the same rate.

In many countries, age-graded classrooms also serve to socialize children, providing opportunities to make friends, to form peer groups, and to participate in team sports. Some of these activities may not seem critical to learning, but there is a broad base of research suggesting that peer learning is uniquely effective. If learning and schooling were no longer age-graded, other institutions would have to emerge to provide these opportunities. Finally, if primary and secondary schooling are no longer age graded, then higher education could no longer expect all incoming students to be the same age, and this would result in dramatic transformations of traditional universities.

3. Diffusion of education

Museums and public libraries might play an increasingly larger role in education. They could receive increased funding to support their evolution into learning resource centers, perhaps even receiving an increasingly large portion of government education funding. They could participate in several ways: for example, by developing curriculum and lesson plans and making these available to students anywhere over the internet, and by providing physical learning environments as they redesign their buildings to support schooling. Science centers have already taken the lead in this area, developing inquiry-based curricula and conducting teacher professional development, but art and history museums may soon follow suit.

The boundary between formal schooling and continuing education will increasingly blur. The milestone of a high school diploma could gradually decrease in importance, as the nature of learning in school begins to look more and more like on-the-job apprenticeship and adult distance education. The \$100 computer and the inexpensive handheld allow for learning to take place anywhere, anytime; 16 year olds could work their part-time jobs during the day and take their classes at night, just like adults do now. Many types of knowledge are better learned in workplace environments; this kind of learning will be radically transformed by the availability of anywhere, anytime learning, as new employees take their laptops or handhelds on the job with them, with software specially designed to provide apprenticeship support in the workplace. Professional schools could be radically affected; new forms of portable just-in-time learning could increasingly put their campus-based educational models at risk.

The relationship between the institution of school and the rest of society may need to change, as the internet allows learners to interact with adult professionals outside the school walls, and as classroom activities become increasingly authentic and embedded in real-world practice.

The internet enables learning to take place anywhere. For example, as of 2005, 22 US states had established online virtual schools; during the 2003-2004 school year, the Florida Virtual School became the state's 73rd school district, and now receives per-student funding from the state just like any other district. In the 2004-2005 school year, 21,000 students enrolled in at least one of its courses (Borja, 2005).

The term "Web 2.0" is often used to refer to a shift in internet usage to more active forms of participation, where all users contribute content and play the role of both producer and consumer (as opposed to "Web 1.0" where experts generated content and users were primarily limited to the role of consumer). Web 2.0 includes wikis, blogging, multiplayer online games, and modding and mash-ups. Many education researchers are experimenting with *Second Life*, an internet-based virtual world where individuals can create on-screen characters called *avatars*, and then communicate with each other through their keyboards. Many university instructors have created classrooms in Second Life; at the Open University in the United Kingdom, the Schome project (www.schome.ac.uk) has created online learning communities for both teenagers and adults. This has led some to suggest that education might experience a similar shift to Education 2.0 - a world that supports collaborative learning, active participatory learning, and new forms of inquiry: new forms of engaging with knowledge (TLRP, 2008).

However, there are many challenges posed when Web 2.0 technologies are introduced into schools. The TLRP report *Education 2.0?* (TLRP, 2008) has noted that Web 2.0 challenges traditional notions of authority, authorship, and integrity; this may be welcomed by some, but resisted by others. The structure of the curriculum could change radically, even to an extreme of learners developing their own curricula. The challenge is to find a way to harness the collaborative and participatory power of Web 2.0, while retaining valued curricular goals and guidance of experts and teachers.

4. Organizational learning

The organizations that thrive will be those that successfully master the challenges of organizational learning and knowledge management. Future schools will face these challenges.

Organizational learning refers to the activities, processes, and structures through which individuals "acquire, share, and combine knowledge through experience with one another" (Argote, Gruenfeld and Naquin, 2001, p370). Organizational learning processes can be explicitly designed with the goal of increasing organizational learning, or they can be emergent and informal. Organizational learning is an emergent property of groups, and cannot be equated with the sum of the individual learning that happens in the members of the organization.

Knowledge management refers to the processes and structures that retain and distribute knowledge in an organization. Without knowledge management, organizational learning can only be of limited effectiveness, because organizational learning occurs at the team level (Edmondson, 2002), and therefore large complex organizations need systems in place to disseminate knowledge among teams.

Knowledge management has proven to be a difficult task. Several software vendors offer products that purport to accomplish knowledge management - databases where knowledge workers are to enter important information about their experiences with projects, customers, or challenges, marked with keywords that would allow later retrieval by anyone in the organization. However, almost all companies that have implemented such systems have found them to be of extremely limited value; in most cases, staff rather quickly stops using the system altogether.

Most schools today are structured as highly bureaucratic and top-down organizational forms. Such organizational forms have proven to be the least effective at successful organizational learning and knowledge management. A challenge moving forward is for schools to revise their organizational forms to enable adaptive and agile learning and knowledge management. Teacher professional development communities are one promising attempt in this direction (Fishman and Davis, 2006).

5. Educational professionals

In one vision of the innovation economy, the teacher becomes a creative worker, jointly constructing knowledge with learners in a creative classroom. Teachers are considered to be creative professionals, and are trained and rewarded accordingly. Sawyer (2004) has argued that creative teaching involves *disciplined improvisation*: the ability to draw on the routines and practices that are acquired through experience, but to modify them improvisationally to respond to each classroom's needs at the moment. Disciplined improvisation acknowledges the benefits of frameworks; well-designed curricula are necessary to effectively scaffold constructivist learning. To create an improvisational classroom, the teacher must have a high degree of *pedagogical content knowledge*—to respond creatively to unexpected student queries, a teacher must have a more profound understanding of the material than if the teacher is simply reciting a preplanned lecture or script (Feiman-Nemser and Buchmann, 1986; Shulman, 1987). An unexpected student query often requires the teacher to think quickly and creatively, accessing material that may not have been studied the night before in preparation for this class; and it requires the teacher to quickly and improvisationally be able to translate their own knowledge of the subject into a form that will communicate with that student's level of knowledge.

There are, however, some who espouse a very different vision: of a scripted, "teacher-proof" classroom such that just about anyone would be capable of serving as a teacher. In this vision, sometimes known as "direct instruction," education researchers and curriculum experts develop a highly detailed lesson plan for each class session: so detailed that, in some cases, all of the teacher's utterances are scripted. In schools that have implemented this vision, teachers are reprimanded if they diverge from the official script that appears in their lesson plan. In such classrooms, the only skill required of a teacher is the ability to read the script, speak clearly, and manage the students to maintain a focused classroom.

This vision of the de-skilled teacher aligns with the credentialist, instructionist paradigm that I described earlier, and learning sciences research suggests that such a curriculum is not capable of generating creative graduates. Consequently, this vision also aligns with the possibility that the economy could become radically deskilled.

Even if such a vision comes to pass in the great majority of schools, there are likely to continue to be creative classroom options available to those who can afford it. The risk is of a social order that reproduces itself through these imbalances in the education system: deskilled classrooms for the majority of citizens, which prepare them only for

deskilled labor, and creative classrooms for a privileged elite, who have been tapped to move into those few professions that continue to require creativity.

Related to these two competing visions of the teacher is the possibility that the role of "teacher" could devolve into multiple roles. For example, the teaching profession could become multi-tiered, with master teachers developing curriculum in collaboration with software developers and acting as consultants to schools, and learning centers staffed by a variety of independent contractors whose job no longer involves lesson preparation or grading, but instead involves mostly assisting students as they work at the computer or gather data in the field (Stallard and Cocker, 2001).

The challenges to any transformation of the teaching profession are likely to include resistance from teachers' professional organizations, unless the transformations are handled with great sensitivity and political skill. A second challenge would be faced by institutions of higher education responsible for preparing these educational professionals; they currently are designed to prepare for a single, unified teaching profession. In most countries, teachers are certified by government bodies, and before educational certification could become multi-tiered, complex political and institutional processes would have to take place.

Possible Future Scenarios

In the face of the above variables, factors, and pressures, a society's response to the age of innovation could move down a range of different paths. I group my comments into the six scenarios that are outlined in the OECD report *What Schools for the Future?* (OECD, 2001). I believe these still best represent the possible range of futures.

Scenario 1: Robust bureaucratic school systems

Schools continue much as they are today. They are characterized by strong, centralized bureaucracies, with standardization and uniformity emphasized. Despite all of the forces identified above, in Scenario 1 schools as institutions prove to be extremely resistant to radical change. This could result due to a combination of vested interests, powerful stakeholders, and parents who prefer only gradual change in schools. It could also result from the importance of the non-classroom functions of schools: providing a place for two-career parents to place their children during the day, socialization, sorting and selection, and the credentialing function.

Forces that work against Scenario 1 include the growing power of learners and parents as producers and participants in learning ("Education 2.0"), the impact of ICT in disseminating learning outside the classroom walls, and a potential crisis in the teacher workforce (which, if taken to an extreme, results in Scenario 6).

Scenario 2: Extending the market model

Advocates of a politically conservative approach - those who hold that the free market always provides better and more efficient solutions - will continue to argue that education should be privatized. An open market of free competition, they argue, will allow educational innovations to be tried, and the successful ones will thrive and propagate. The current centralized government model, they argue, is incapable of innovation due to standardization and top-down control.

In Scenario 2, the conservative vision comes to pass, perhaps due to increasing dissatisfaction with public schools. Government funding is distributed directly to parents, who then choose from a range of educational offerings. Privately-run, for-profit learning centers might begin to offer a three-hour intensive workday, structured around tutors and individualized educational software, with each student taking home his or her laptop to complete the remainder of the day at home. In the US, one of the largest for-profit educational franchises is Sylvan Learning Centers; these storefront operations could expand dramatically if given access to government funding. Because curriculum and software would be designed centrally, and the software does the grading automatically, these tutors could actually leave their work at the office - unlike today's

teachers, who stay up late every night and spend all weekend preparing lesson plans and grading. For those parents who need an all-day option for their children due to their work schedule, for-profit charter schools could proliferate, each based on a slightly different curriculum or a slightly different software package. Particularly skilled teachers could develop reputations that would allow them to create their own "start-up schools," taking 10 or 20 students into their home for some or all of the school day - the best of them providing serious competition for today's elite private schools, and earning as much as other knowledge workers such as lawyers, doctors, and executives.

The history of innovation suggests that frequent experimentation is necessary for innovation to occur. To enhance innovation, educational systems must develop some way to allow frequent variations to be attempted, and some method for selecting and disseminating the best of these innovations. The innovations must be sustainable over time, and they must be scalable to large numbers of schools and districts. The market is one such mechanism for selection and dissemination; if Scenario 3 is rejected, then another such mechanism must be proposed and implemented.

One risk of allowing competition and innovation in the free market is that the education system could fragment, with some schools offering a creative education (possibly for a small elite) and other schools offering credentialist training in specific, narrowly tailored sets of job-specific skills.

Scenario 3: Schools as core social centers

Schools are largely viewed as successful and are widely respected as playing a central function in society. The level of public support for schools increases, as a broad public recognizes that schools perform a necessary public role. Schools are viewed as centers of a community, and as serving not only the function of educating individuals, but also as serving a collective function of community building and social capital formation. Poor areas receive increased funding to accommodate their relatively greater need.

Schools as core social centers not only serve full-time primary and secondary students, but also play a role in adult and continuing education. Schools become less bureaucratic and more diverse. The boundaries marking one school level from the next become more flexible, as learning is increasingly viewed as a lifelong process. There is greater mixing of ages, and increased youth-adult activities.

Schools work increasingly closely with other community institutions (libraries, museums, social service agencies), viewing themselves as one node in a network. The professional role of teacher evolves to collaborate more closely with other sources of community expertise. Thus the local role of schools becomes much more critical; centralization and uniformity at the national level declines in significance.

Scenario 4: Schools as focused learning organizations

As in Scenario 3, schools enjoy high levels of public trust and increased funding, and equity is an important issue, with poorer schools receiving increased funding to address these disadvantages. Schools reform themselves around a knowledge-society agenda, based in the sort of learning sciences research described earlier in this report. Experimentation and innovation are common, curriculum variations are widespread. More specialized classrooms and schools might emerge (focused for example on the arts, foreign languages and affairs, or technology). Schools retain an important credentialing function, although other forms of credentialing may also emerge; new forms of assessment frequently appear.

Schools become true learning organizations, capable of generating and disseminating innovation. Organizational structures become flatter, with a reduction in hierarchical levels as teams of teachers take on leadership responsibilities. Teachers are viewed as knowledgeable professionals and are more motivated and more highly paid. There is an increasing mobility in and out of teaching and other professions. Compared to Scenario 3, teaching remains a distinct profession with a clear identity, but with more frequent mobility and with more connections to other professionals than in Scenarios 1 or 2.

Students often work in small groups, in environments that include not only teachers but other knowledge workers. There may be a wide variety in age grading and ability mixes. ICT is widespread, as are network and communication links outside the schools to other knowledge industries and creative industries.

Scenarios 3 and 4 both display similarities to the future envisioned by the New Horizons for Learning team (www.newhorizons.org), as presented for example in (Dickinson, 2000): schools replaced by community learning centers and radically elaborated public libraries—open 18 hours a day—and early childhood parenting centers.

Scenario 5: Learner networks and the network society

Several trends that I have identified above - the diffusion of education, diverse knowledge sources, and customization - if taken to an extreme could result in a scenario in which schools as we know them become obsolete. (The OECD report refers to Scenarios 5 and 6 as “de-schooling” scenarios.) Today’s large public schools were designed in an industrial era and were based on instructionism, an outmoded model of schooling. Roger Schank (1999) and Seymour Papert (1980) have argued that computer technology is so radically transformative that schools as we know them will have to fade away before the full benefits can be realized. It may be impossible to implement alternative models of learning in the institution that today we know of as school. If today’s schools cannot adapt rapidly enough, parents may increasingly abandon schools and seek other alternatives. The flight from schools would begin with the educated classes, and also with various religious and interest groups. Under pressure from parents, politicians may follow this by reducing funding for schools and increasing funding for other options.

If education diffuses radically, schools may no longer be physical locations where everyone goes to learn; learning could take place at home, on the job, or online. Imagine a nation of online home-based activities organized around small neighborhood learning clubs, all connected through high-bandwidth internet software. There would be no textbooks, few lectures, and no curriculum as we know it today. New forms of credentialing, assessment, and competence measures could proliferate. Software, media, and publishing companies could innovate new forms of curriculum and learning delivery that could accelerate Scenario 5. “Teachers” would operate as independent consultants who work from home most of the time, and occasionally meet with ad-hoc groups of students at a learning club. Each meeting would be radically different in nature, depending on the project-based and self-directed learning that those students were engaged in. In fact, each type of learning session might involve a different learning specialist; new types of learning professionals might emerge - for example, staffing telephone or internet helplines for students, or offering home visits for short tutoring sessions.

Variations of Scenario 5 are commonly presented by education futurists; “Education 2.0” falls in this category. Scenario 5 supports flexibility, extremely customized learning for each individual, and networked and disseminated learning. One risk, however, is that those at the lowest socioeconomic levels could be left behind in this transformation; a few schools might remain to serve these most disadvantaged students. These may or may not be well-funded institutions, depending on the commitment of society to educating even its poorest citizens.

A second challenge is how Scenario 5 could satisfy the non-classroom functions currently performed by schools: for example, providing a safe place for children while parents work during the day, providing socialization opportunities with peers. Scenario 5 could not come to pass unless other institutions emerged, in parallel with the de-schooling process, to take on these functions.

Scenario 6: Teacher exodus—the “meltdown” scenario

As in Scenario 5, schools are unable to respond to these broad societal shifts, due to institutional inertia. Public respect for schools declines, and funding drops, to the point where schools are no longer able to attract qualified teachers. As today’s teachers

retire, and the knowledge society demands increasingly high qualifications for teachers, communities may not be willing to increase funding levels as necessary to attract the teachers needed in the knowledge society.

We are likely to see a wide range of responses to the teacher shortage, from innovative to traditional. One response will be to move to a deskilled teaching profession, with scripted and "teacher-proof" curricula. Other responses will include an increasing use of ICT as an alternative to teachers.

If this scenario comes to pass, educational equity will be a key challenge. For example, several futurists have predicted that automatization will accelerate dramatically so that an increasing number of jobs can be automated (Pink, 2005). This trend could combine with increased globalization such that unskilled jobs would almost all relocate to low-wage countries. The effect on advanced economies would be to create a radically tiered social structure, with a few highly paid creative knowledge workers at the top, and the great majority of the workforce having extremely limited job opportunities (apart from service sector jobs, such as waiting on tables or repairing automobiles, that are resistant to automatization and outsourcing).

In such a society, it would become politically difficult to argue that creative abilities were required of all citizens. In a difficult budgetary and funding environment, it might begin to be perceived as inefficient to invest in a learning sciences-based education for the entire workforce if only a small percentage of workers would eventually need those skills. A tiered educational system could then emerge, with a small cadre of creative and highly paid teachers educating the creative workers of the future, and a much larger cadre of relatively unskilled teachers simply executing scripted curricula.

Final challenges

I believe that some combination of Scenarios 3, 4, and 5 represent the best form of schooling for the innovation age. However, there are substantial societal and institutional forces in place that work against any transformation to such a future. To avoid Scenarios 1, 2, or 6, learning sciences researchers will have to develop four broad categories of materials, to work as a unified whole, while allowing for adaptation and customizability:

Textbooks must be rewritten (or even reconceived as laptop-based software packages), to present knowledge in the developmentally appropriate sequence suggested by the learning sciences, and to present knowledge as a coherent, integrated whole, rather than as a disconnected series of decontextualized facts. This poses substantial challenges for private textbook publishers, and for the school leaders who review and approve textbooks.

Curricular units must be prepared that are suitable for teachers to draw on and adapt to the unique needs of each classroom. These could be developed by private publishers, or a form of open-source community of educators could emerge to allow teachers to share and build on their own curricular innovations (several such communities exist online today; see Fishman and Davis, 2006).

Educational software that is based on learning sciences principles must be made commercially available. This poses substantial challenges for the private companies that develop such software. Exciting new learning applications are emerging from university research laboratories, but few of these are being developed into commercial products - in large part, because other aspects of schools, identified in this report, also need to change before such applications can be successfully implemented.

Assessments must be developed that assess deep knowledge instead of surface knowledge, and to take into account the fact that due to customization, different learners might learn different subject matter (Pellegrino, Chudowsky and Glaser, 2001). These new forms of assessment do not yet exist, and a clear vision of how such tests

would be constructed has not yet emerged from learning sciences research. A critical issue for the future is to continue this work. Test construction is complex, involving field tests of reliability and validity for example, and will require learning scientists to work with psychometricians and policy experts (Pellegrino, Chudowsky and Glaser, 2001).

In addition to these scholarly challenges, an even bigger challenge to assessment reform is likely to be political. It will not be easy to convince those government bodies responsible for educational assessment to transition to these fundamentally new assessments—in no small part because parents may resist the use of tests that look very different from the ones they experienced in school. A further political difficulty is that during the transition period to learning-sciences based classrooms and deeper forms of assessment, there is likely to be a period of several years during which different children are likely to excel at the new assessments than at the old. Those parents whose children seem to be disadvantaged by lower scores are likely to actively resist the new assessments.

Conclusion

We are entering the innovation age. In the decades ahead, as the nations of the world respond to the demand for innovation, creativity will be increasingly valued. There are no forces at present, and none potentially on the horizon, that would result in a return to an industrial-age economy; no forces that would reduce the importance of creativity to society and the economy.

However, the innovation age could unfold along a broad range of paths. The most humanistic, liberal view is of a world where all people realize their full creative potential through effective educational institutions and work environments, and find fulfillment through creative work and creative leisure activities. However, a more class-based outcome is also possible - a world in which a small creative elite is capable of generating sufficient innovation to grow the economy, with the remainder of the workforce continuing to engage in scripted, process-managed, uncreative work.

Based on my best understanding of innovation research, I believe that this pessimistic outcome is unlikely - because the most innovative companies are those that foster and demand innovation from all of their employees, rather than a small elite. Decades ago, many industrial-age companies had a research and development team that functioned as a creative elite; all new ideas were expected to come from this team, and the rest of the company was simply expected to execute, to follow instructions with almost no creativity required. In recent decades, this model has proven to be ineffective, and the most innovative companies have shifted to organizational designs that foster creativity throughout the organization.

To maximize innovation and knowledge generation, many societal factors must be in alignment. In closing I emphasize two: first, the broader society must foster knowledge communication and dissemination, through enhanced social networks, transportation infrastructures, and communication technologies. Second, learning must be available to all citizens throughout the lifespan, and this learning must be designed to support creative behaviour. At present, many schools (and corporate learning programmes as well) are based in an cultural model of teaching and learning that I have called the "standard model." I have argued that the standard model does not result in learning that supports creative behaviour. Fortunately, research emerging from the learning sciences is showing how to design learning environments that result in creative learning.

I have identified a range of challenges that must be overcome before schools and other organizations can successfully redesign learning environments on learning sciences principles. For the future of creativity and innovation, it is critical that societies overcome these challenges and build creative classrooms designed for the innovation age.

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