

Technological Supports for Acquiring 21st Century Skills

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Glossary:

augmented reality: a simulated experience created by interweaving real and digital people, places, and objects

avatar: the digital representative of a participant in a virtual world

complex communication: the ability to help others master complicated concepts through providing a variety of explanations and examples

data mining: techniques used to find and interpret interesting patterns in very large datasets

digital literacy: types of fluent use of tools, applications and media to accomplish complex tasks

expert decision making: the ability to solve difficult problems for which all standard methods of problem solving fail

immersive media: emerging media, such as multi-user virtual environments and augmented realities, in which the user has the sensation of being present in a digitally created world

multi-user virtual environment (MUVE): a virtual world containing the avatars of users, computer-based agents, and digital artifacts

situated learning: learning through apprenticeships and mentoring on authentic, real-world tasks

Abstract:

The 21st century seems quite different than the 20th in the capabilities people need for work, citizenship, and self-actualization. In response, society's educational systems must transform their objectives, curricula, pedagogies, and assessments to help all students attain the sophisticated outcomes requisite for a prosperous, attractive lifestyle based on effective contributions in work and citizenship. This article describes an innovative strategy by which new pedagogies based on emerging immersive media can aid all students in attaining sophisticated 21st century skills and knowledge.

Skills Needed for 21st Century Work and Citizenship

The 21st century seems quite different than the 20th in the capabilities people need for work, citizenship, and self-actualization. In response, society's educational systems must transform their objectives, curricula, pedagogies, and assessments to help all students attain the sophisticated outcomes requisite for a prosperous, attractive lifestyle based on effective contributions in work and citizenship. This article describes an innovative strategy by which new pedagogies based on emerging immersive media can aid all students in attaining sophisticated 21st century skills and knowledge.

Thus far, the 21st century has seen a dramatic shift in the economic model for industrialized countries. Systems of economic development based on geography, trade rules, and tariffs; slow dissemination of scientific and technological discoveries; and long cycles of product life have given way to global trade, rapid product innovation, the lowering of trade barriers, rapid dissemination of scientific and technological discovery, and quick global deployment and movement of capital and the means of production. In the early 21st century, income and wealth come from applying technology and novel ideas to create new products and processes. Adding value to products and processes is the key to growing jobs and incomes in this new economic environment.

Numerous reports on the global, knowledge-based economy and the "flat" world document that tomorrow's workers must be prepared to shift jobs and careers more frequently, to be flexible and adaptable in acquiring job skills, and to integrate and focus a changing mix of job-derived and education-based knowledge on business processes and problems. As the global economy continues to evolve, predictions are that workers will change jobs seven or eight times during their work life. The worker of the 21st century must

have science and mathematics skills, creativity, fluency in information and communication technologies, and the ability to solve complex problems; these are also important capabilities for citizenship at the local, national, and global level.

Further, the types of work done by people, as opposed to the kinds of labor done by machines, are continually shifting as computers and telecommunications expand their capabilities to accomplish human tasks. Economists Frank Levy and Richard Murnane (2004) have documented a very important aspect of what constitutes 21st century understandings and performances:

Declining portions of the labor force are engaged in jobs that consist primarily of routine cognitive work and routine manual labor—the types of tasks that are easiest to program computers to do. Growing proportions of the nation’s labor force are engaged in jobs that emphasize expert thinking or complex communication—tasks that computers cannot do. (pp. 53–54)

These economists go on to explain that “expert thinking [involves] effective pattern matching based on detailed knowledge; and metacognition, the set of skills used by the stumped expert to decide when to give up on one strategy and what to try next” (Levy & Murnane, 2004, p. 75). What a skilled auto mechanic does when all diagnostic systems show normal functioning, but the car is still malperforming is expert decision making: inventing new problem solving heuristics when all standard strategies have failed.

“Complex communication requires the exchange of vast amounts of verbal and nonverbal information. The information flow is constantly adjusted as the communication evolves unpredictably” (Levy & Murnane, 2004, p. 94). A skilled teacher is an expert in complex

communication, able to improvise answers and facilitate dialogue in the unpredictable, chaotic flow of classroom discussion.

21st century education should prepare students for a world in which almost all types of routine cognitive tasks are done by computers and in which expert thinking and complex communications are the core intellectual capabilities by which people attain prosperity and economic security individually, as a region, and as a nation. These higher order performances are based on fundamental knowledge about how to do simpler types of work, so the shift needed is not to remove the learning of routine cognitive skills (such as basic arithmetic operations) from the curriculum. Rather, the fundamental change involves deemphasizing fluency in simple procedures as an end-goal of preparation for work and life (e.g., counting bills as a bank teller), instead using these routine skills as a substrate for mastering complex mental performances valued in the future workplace, such as advising clients about global investment strategies tailored to their individual situations.

Thus, a crucial challenge for education in all countries is to align curriculum and learning to new economic and governance models based both on a global, knowledge-based workplace and on emerging world-level problems such as human-induced climate change (Friedman, 2008). To accomplish this we must transform children's learning processes in and out of school and engage student interest in gaining 21st century skills and knowledge for work, citizenship, and a satisfying lifestyle.

Organizing 21st Century Skills into a Curricular Framework

A variety of groups have developed frameworks that describe 21st century skills students should master as part of their education. Space does not permit summarizing and comparing all these descriptions. Such litanies of 21st century skills often lack clarity about

why a skill is 21st Century, as opposed to knowledge generically useful at any point in history. Determining what constitutes a 21st Century Skill requires stipulating the metrics by which one judges whether a human performance is truly significant in its projected importance to attaining an attractive, prosperous job and lifestyle – and also is sufficiently different from 20th Century Skills to merit inclusion. Assessing the degree to which the capability is valuable in work and citizenship is key to these metrics, as is distinguishing in kind between perennial and contextual performances.

For example, collaboration is a perennial capability, always valued as a trait in workplaces across the centuries; as such, the basic value of this interpersonal performance is not intrinsically special to our emerging economic context. However, the degree of importance for collaborative capacity is growing in an era where work is increasingly done by teams of people with complementary expertise and roles, as opposed to individuals doing manual operations on an assembly line. Thus, even though perennial in nature, collaboration is worthy of inclusion as a 21st century performance because, for the context in which today's students will function as adults, the importance of cooperative interpersonal capabilities is substantially higher than in the prior industrial era.

In contrast, the ability to rapidly filter huge amounts of incoming data, extracting information valuable for decision making, is a contextual capability. Due to the prevalence of information and communications technologies (ICT), for the first time in human history people are inundated by enormous amounts of data that they must access, manage, integrate, and evaluate. The ability to separate signal from noise in a potentially overwhelming flood of incoming data is a 21st century performance not in degree – because this is novel in history as a valuable capability – but in *kind*. This distinction is important because, unlike perennial

capabilities, new types of human performances are typically not part of the legacy curriculum inherited from 20th century educational systems.

Some frameworks for 21st century skills discuss new literacies based on the evolution of ICT (Dede, 2008). For example, Jenkins and his colleagues (2006) delineate a set of novel literacies based on new media (page 4):

Play — the capacity to experiment with one’s surroundings as a form of problem-solving

Performance — the ability to adopt alternative identities for the purpose of improvisation and discovery

Simulation — the ability to interpret and construct dynamic models of real-world processes

Appropriation — the ability to meaningfully sample and remix media content

Multitasking — the ability to scan one’s environment and shift focus as needed to salient details.

Distributed Cognition — the ability to interact meaningfully with tools that expand mental capacities

Collective Intelligence — the ability to pool knowledge and compare notes with others toward a common goal

Judgment — the ability to evaluate the reliability and credibility of different information sources

Transmedia Navigation — the ability to follow the flow of stories and information across multiple modalities

Networking — the ability to search for, synthesize, and disseminate information

Negotiation — the ability to travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative norms

This list illustrates how 21st century skills, such as collaboration and information filtering, are linked to the capabilities of emerging interactive media.

Dede (2005, page 15) describes the types of learning strengths, styles and preferences neomillennial students acquire from their use of immersive collaborative media, such as multiplayer online games or virtual environments like Second Life:

- Fluency in multiple media, valuing each for the types of communication, activities, experiences, and expressions it empowers.
- Learning based on collectively seeking, sieving, and synthesizing experiences, rather than individually locating and absorbing information from some single best source.
- Active learning based on experience (real and simulated) that includes frequent opportunities for reflection.
- Expression through non-linear, associational webs of representations rather than linear “stories” (e.g., authoring a simulation and a webpage to express understanding, rather than a paper).
- Co-design of learning experiences personalized to individual needs and preferences.

As discussed later, using immersive collaborative simulations in classroom settings offers a powerful method to nurture 21st century skills.

Leu and his colleagues describe four characteristics of the “new literacies” generated by ICT. First, emerging ICT tools, applications, media, and environments require novel skills, strategies, and dispositions for their effective use. Second, new literacies are central to full economic, civic, and personal participation in a globalized society. Third, new literacies constantly evolve as their defining ICT continuously are renewed through innovation. Fourth, new literacies are multiple, multimodel, and multifaceted.

Leu’s third point raises important issues about stability: How durable are 21st century performances in their applicability to work, citizenship, and self-actualization? How quickly will additional, important 21st century understandings and behaviors emerge as ICT continue to evolve? Certainly, tools, applications, media and environments are changing rapidly, with no end in sight. Typically, despite predictions of paperless offices or the end of the book, this evolution involves adding additional literacies and understandings rather than new performances displacing previously useful behaviors. Examining predictions about the future of ICT helps to illuminate what these additional literacies may be and what knowledge and skills may become less useful over time.

Overall, the skills advocated by various group as “21st century” are sophisticated cognitive, affective, and psychosocial performances generally manifested through fluent use of digital tools and media. In the 21st century, people frequently use ICT to accomplish objectives never before attainable (e.g., remote collaboration via groupware among a team scattered across the globe). How can we not only prepare today’s students for the new jobs generated by these capabilities, but also build their capacity to hold novel careers that will emerge a decade or two from now based on future breakthroughs in ICT and, increasingly, in biotechnology?

An Innovative Strategy for Teaching Illustrative 21st Century Skills

The remainder of this article describes how innovative, technology-aided pedagogies can help students learn sophisticated cognitive, affective, and psychosocial performances important for 21st century work and citizenship. A cluster of 21st century skills neglected in most current curricula is “collective problem resolution via mediated interaction.” In 21st century work, knowledge is grounded in a setting and distributed across a community, rather than abstract and isolated within individuals. Problem *finding* (the front-end of the inquiry process: making observations and inferences, developing hypotheses, and conducting experiments to test alternative interpretations of the situation) is crucial to reaching a point where the work team can do problem solving. Individual and collective metacognitive strategies for making meaning out of complexity (such as making judgments about the value of alternative problem formulations) are vital.

Each person involved in this interrelated suite of 21st century skills has strong strategies both in effective pattern matching based on detailed knowledge and in judging when to give up on a particular problem solving strategy to instead try another approach.

Individuals on the work team are adept at manipulating sophisticated ICT applications and representations utilized within the complementary perspectives they bring to bear (e.g., using a spreadsheet to examine financial hypotheticals). They also are skilled in expressing core insights from their knowledge to others who have different backgrounds and experiences. Richly interactive complex communication among team members is not limited to face-to-face dialogue, but frequently relies on mediated interaction across distance in which the team co-constructs and negotiates shared interpretive understandings and a problem resolution strategy.

For example, a school district might task a team of teachers, school administrators, parents, and local business executives to develop a plan for improving students' educational outcomes in mathematics. Potential factors leading to subpar educational performance include individual differences in native language, gender, culture, and socioeconomic status; teachers' experience and preparation in mathematical content, subject-specific pedagogy, classroom management, and student engagement; state and district policies related to educational reform, the curricular materials used in mathematics, and the capacity of the technology infrastructure at local schools, among others. Under these circumstances, individual and collective skills in problem finding, inquiry, metacognition, collaboration, expert decision making, complex communication, and use of ICT tools, communicative media, and representations are vital to the team's success.

In classroom settings, sophisticated ICT capable of supporting the teaching of such collective problem resolution via mediated interaction are now emerging. This is important because, until this point in history, schools have lacked the capacity to inculcate 21st century skills and knowledge best learned through participation in real-world communities of

practice. Reports such as the National Research Council's *How People Learn* cite *situated* theories of learning (mentoring and apprenticeships in communities of authentic, real-world practice) as powerful in life, but very difficult to achieve in school settings. Emerging interactive media now have the capability to redress this deficit, a vital advance in teaching many 21st century skills.

Emerging Media for Situated, Immersive, Collaborative Simulation

Three complementary technological interfaces are currently shaping how people learn, with multiple implications for K-12 education:

- The familiar “world- to- the- desktop” interface provides access to distributed knowledge and expertise across space and time through networked media. This interface provides the models for learning that now underlie most tools, applications, and media in K-12 education.
- Emerging multi-user virtual environment (MUVE) interfaces offer students an engaging Alice-in-Wonderland experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other participants and with computerized agents. Researchers are exploring the affordances of such models for learning in K-12 education.
- Augmented reality (AR) interfaces enable “ubiquitous computing” models. Students carrying mobile wireless devices through real world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or an historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students’ experiences and

interactions. Scholars are starting to study how these models for learning aid students' engagement and understanding.

MUVEs empower creating digital contexts inaccessible in the real world, while AR enables the infusion of virtual contexts within physical locations. For reasons of space, only the MUVE interface is used as an example of immersive collaborative simulation to teach 21st century skills.

In a MUVE, knowledge is grounded in a setting and distributed across a community, rather than isolated within individuals. Contrary to conventional K-12 instruction where knowledge is decontextualized and explicit, in MUVEs the learning is situated and tacit: Problem finding is central to problem solving. This parallels the nature of 21st century work, as well as the learning styles and strengths of today's digital-age students.

The Power of Situated Learning for Inculcating 21st Century Performances

Situated learning requires authentic contexts, activities, and assessment coupled with guidance from expert modeling, mentoring, and legitimate peripheral participation. As an example of legitimate peripheral participation, graduate students work within the laboratories of expert researchers, who model the practice of scholarship. These students interact with experts in research as well as with other members of the research team who understand the complex processes of scholarship to varying degrees. While in these laboratories, students gradually move from novice researchers to more advanced roles, with the skills and expectations for them evolving. Potentially quite powerful, situated learning is much less used for instruction than because classrooms are by design isolated from the real world to encourage reflection and to provide custodial care. However, immersive interfaces can draw

on the power of situated learning even in school settings by enabling collaborative simulations with problems and contexts similar to the real world.

Situated learning is important in part because of the crucial issue of transfer. Transfer is defined as the application of knowledge learned in one situation to another situation and is demonstrated if instruction on a learning task leads to improved performance on a transfer task, typically a skilled performance in a real-world setting. One of the major criticisms of instruction today is the low rate of transfer generated by conventional instruction. Even students who excel in schooling or training settings often are unable to apply what they have learned to similar real-world contexts. Situated learning addresses this challenge by making the setting in which learning takes place similar to the real-world context for performance in work or personal life. Learning in well-designed digital contexts can lead to the replication in the real world of behaviors successful in simulated environments.

Moreover, the evolution of an individual's or group's identity is an important type of learning for which simulated experiences in immersive interfaces are well suited. Reflecting on and refining an individual identity is often a significant issue for students of all ages, and learning to evolve group and organizational identity is a crucial skill in enabling innovation and in adapting to shifting contexts. The social sciences see both the self and the organization as often fragmented, with complementary parts, rather than centralized and unitary. Identity "play" through trying on various representations of the self and the group in virtual environments provides a means for different sides of a person or team to find common ground and the opportunity for synthesis and evolution, vital for the affective and psychosocial aspects of learning 21st Century skills.

Immersion is important in this process of identity exploration because virtual identity is unconstrained by physical attributes such as gender, race, and disabilities. Virtual environments based on games and simulations illustrate how participants take advantage of fluidity in the identities they present. Simulations in virtual environments and augmented realities increase the value of these explorations by providing realistic feedback on how the real world responds to various patterns of individual and group behavior.

But what is so special about the situated learning now enabled in classrooms by emerging media? After all, outside of school contexts students have opportunities for situated learning without using technology. One attribute that makes mediated immersion different and powerful is the ability to access information resources and psychosocial community distributed across distance and time, broadening and deepening experience. A second important attribute is the ability to create interactions and activities in mediated experience not possible in the real world, such as teleporting within a virtual environment, enabling a distant person to see a real-time image of your local environment, or interacting with a (simulated) chemical spill in a busy public setting. Both of these attributes are actualized in immersive interfaces.

Learning 21st Century Skills in the River City MUVE

With funding from the National Science Foundation, for almost a decade years my colleagues and I have used design-based research methods to study an educational MUVE called River City. In the River City MUVE, a participant takes on the identity of an avatar, a virtual persona in the world and communicates with other participants' avatars via text chat and virtual gestures. In this graphical virtual context (Figure 1), participants also interact

with digital artifacts, such as viewing pictures or manipulating tools (e.g., an online microscope), as well as with computer-based agents (figure 2).

<figures 1 and 2 near here>

The River City curriculum is a middle school science unit designed around national content standards and assessments in biology, ecology, epidemiology, and scientific inquiry. Students work in teams of three to collaboratively solve the problem of why the residents of River City are falling ill. Students travel back in time—into a series of virtual worlds—to the period in history that scientists were just discovering bacteria.

The curriculum is historically accurate and contains pictures from the Smithsonian Institute that help to portray accurate picture of what the time period was like. The River City virtual “world” is an industrial 18th century city with a river running through it (see Figure 3). Different forms of terrain influence water runoff in the various neighborhoods (wealthy area, middle class area and tenements). Digital artifacts include audio clues of sick residents coughing or mosquitoes buzzing, as well as images from that period in history (Figure 4).

<figures 3 and 4 near here>

Engaging in inquiry also involves students learning how to collect data and test their hypotheses and use the tools of scientists, such as an online microscope. For example, they can use the virtual microscope to take water samples from one of the water sampling stations in the city (figures 5 and 6).

<figures 5 and 6 near here>

Students use 21st century knowledge and skills to identify a problem and then develop and test a hypothesis based on one of the three disease strands infecting the city (i.e.,

insect-born, air-born, and water-born). After testing their hypotheses, students analyze their data and then write up their research in the form of a report to the mayor of River City. The report, based on the concept of a lab report, describes their experiment, research findings, conclusions, and recommendations for how the mayor can stop the spread of illness in River City.

We have found that these reports to be accurate representations of students' inquiry learning. From a technical standpoint, MUVES are unique in their ability to keep minutely detailed records of the moment-by-moment movements, actions, and utterances of each participant in the environment. With the data-tracking system, we are able to collect, store, and retrieve information on the activities of each student as s/he explores the MUVE. These data form the basis of a personal MUVE history of each student that follows him or her from session to session, in the form of extensive log files—a feature impossible to replicate in a classroom-based experience. The level of detail in these records is extensive: the logs indicate exactly where students went, with whom they communicated, what they said in these interactions, what virtual artifacts they activated, and how long each of these activities took. Using data mining techniques on these detailed event-logs provides a powerful lens by which we can study individual student performances of 21st century skills in this learning environment and document gains in students' engagement, learning, and self-efficacy.

Conclusion

This extended example illustrates how situated, immersive, collaborative simulations based on MUVES can aid students in learning 21st century understandings and performances, such as collective problem resolution via mediated interaction, while in classroom settings. Other immersive interfaces, such as augmented reality, can accomplish similar engagement

and learning. Over time, these interfaces are becoming increasingly prevalent, and research is revealing how best to actualize their potential for learning and teaching.

A huge challenge remains to implementing the strategy implemented in this article: What do we deemphasize in current instruction and assessment to make room for 21st century understandings? The curriculum is crowded with low-level facts and recipe-like procedures (e.g., In what year did Columbus discover America? What are the seven steps of historical inquiry?), as opposed to nuanced understandings and performances (i.e., What confluence of technological, economic, and political forces led to the age of exploration around the end of the 15th century? By what process of interpreting of historical data did you reach this conclusion?).

Downgrading the importance of some material in the current curriculum is much harder than adding content and skills because omission involves “unlearning.” A major challenge in professional development is helping teachers, policy makers, and local communities *unlearn* the beliefs, values, assumptions, and cultures underlying schools’ standard operating practices, such as forty-five minute class periods that allow insufficient time for all but superficial forms of active learning by students. Altering deeply ingrained and strongly reinforced rituals of schooling takes more than the superficial interchanges typical in “make and take” professional development or school board meetings. Intellectual, emotional, and social support is essential for “unlearning” and for transformational relearning that can lead to deeper behavioral changes to create next-generation educational practices. Educators, business executives, politicians, and the general public have much to unlearn if 21st century understandings are to assume a central place in schooling.

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Chris Dede is the Timothy E. Wirth Professor in Learning Technologies at Harvard's Graduate School of Education. His fields of scholarship include emerging technologies, policy, and leadership. His funded research includes four grants from NSF and the US Department of Education to explore immersive and semi-immersive simulations as a means of student engagement, learning, and assessment. In 2007, he was honored by Harvard University as an outstanding teacher. Chris has served as a member of the National Academy of Sciences Committee on Foundations of Educational and Psychological Assessment, a member of the U.S. Department of Education's Expert Panel on Technology, and International Steering Committee member for the Second International Technology in Education Study. He serves on Advisory Boards and Commissions for PBS TeacherLine, the Partnership for 21st Century Skills, the Pittsburgh Science of Learning Center, and several federal research grants. His co-edited book, Scaling Up Success: Lessons Learned from Technology-based Educational Improvement, was published by Jossey-Bass in 2005. A second volume he edited, Online Professional Development for Teachers: Emerging Models and Methods, was published by the Harvard Education Press in 2006.

Figures (also sent separately along with author photo)



Figure1: Aerial View of River City



Figure 2: Avatar and Agent

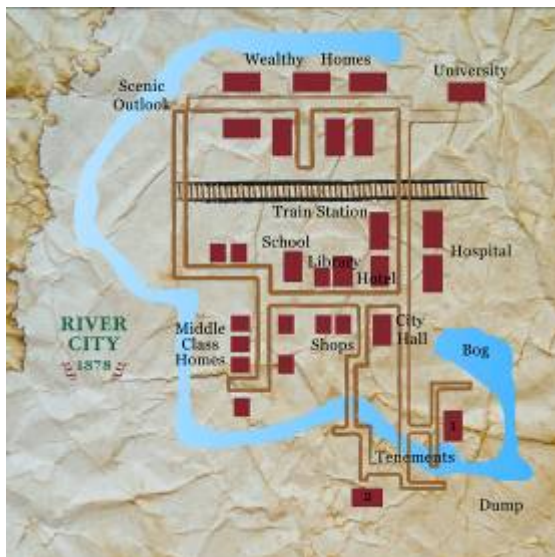


Figure 3: Map of River City



Figure 4: Noted 19th Century Woman Scientist



Figure 5: Taking a water sample with the virtual microscope.

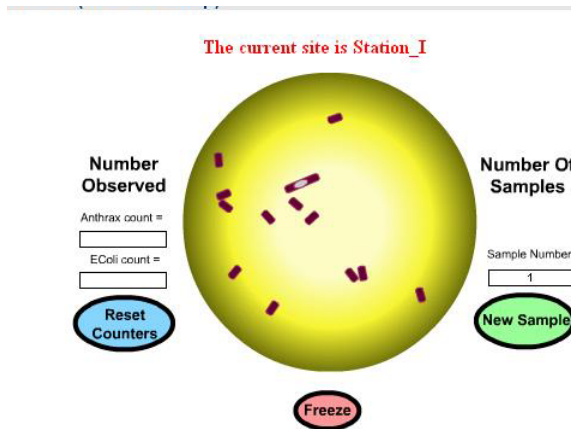


Figure 6: Close up of Microscope. Students click “Freeze” and count the number of EColi and Anthrax in the water.