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EMERGING TECHNOLOGIES FOR COLLABORATIVE, MEDIATED, IMMERSIVE LEARNING

Jody Clarke

Harvard Graduate School of Education, Cambridge, MA, USA

Chris Dede

Harvard Graduate School of Education, Cambridge, MA, USA

Ed Dieterle

Harvard Graduate School of Education, Cambridge, MA, USA

Introduction

Three complementary technological interfaces are now shaping how people learn, with multiple implications for K-12 education (Dede, 2002).

- The familiar “*world-to-the-desktop*” interface provides access to distributed knowledge and expertise across space and time through networked media. Sitting at their laptop or workstation, students can access distant experts and archives, communicate with peers, and participate in mentoring relationships and virtual communities of practice. 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. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures. This type of “mediated immersion” (pervasive experiences within a digitally enhanced context), intermediate in complexity between the

real world and paint-by-numbers exercises in K-12 classrooms, allows instructional designers to construct shared simulated experiences otherwise impossible in school settings. Researchers are exploring the affordances of such models for learning in K-12 education (Clarke et al., 2006; Barab et al., 2004).

- *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. Researchers are starting to study how these models for learning aid students’ engagement and understanding (Klopfer et al., 2004; Klopfer and Squire, in press).

How Collaborative Mediated Immersion Helps Teaching and Learning

Immersion in virtual environments and augmented realities shapes participants’ learning styles, strengths, and preferences in new ways beyond what using sophisticated computers and telecommunications has generated thus far, with multiple implications for K-12 education. Dede (2005) describes learning styles enhanced by mediated immersion in distributed-learning communities based on MUVE and AR interfaces: (a) fluency in multiple media; (b) learning based on collectively seeking, sieving, and synthesizing experiences, rather than individually locating and absorbing information from some single best source; (c) active learning based on experience (real and simulated) that includes frequent opportunities for reflection; (d) expression through nonlinear, associational webs of representations rather than linear “stories” (e.g., authoring a simulation and a webpage to express understanding, rather than a paper); and (e) codesign of learning experiences personalized to individual needs and preferences. These capabilities reflect students’ media-generated learning strengths and preferences on which instruction should build to maximize educational effectiveness.

If we examine students’ technology use outside of school, we see these shifts in learning styles happening in their informal, voluntary educational activities. For example, although one kid sitting in front of a console game is still prevalent, collaborative, mediated gameplay is rising. X-box live and Nintendo DS devices enable participants to interact during gameplay across distance and space. Massive multiplayer online games, such as the World of Warcraft (Blizzard Entertainment) and Everquest (Sony Online Entertainment), bring players together online where they can interact in a virtual collaborative context. Emerging communities such as “modding,” in which users create new content for games (often contributing to a shared database of models), and “machinima,” in which users create new content via video capturing techniques, are further shaping how kids now express themselves via collaborative digital experiences. Youth are forming networked communities around games and movies, in

which they share codes and strategies and build collaborative clans working together to fulfill quests. In their learning processes, many of these distributed communities among kids parallel the activities of twenty-first century professionals in knowledge-based workplaces.

Despite the proliferation of sophisticated technology use outside of schools, typical classrooms seldom leverage any of the three interfaces described earlier for teaching and learning. Moreover, when employed computers and telecommunications are generally used to streamline the delivery of content, ignoring information technology's capabilities to (1) support learning in real-world contexts, (2) connect learners to experts and communities of peers, (3) provide visualization and analysis tools for thinking with data, (4) scaffold problem-solving that enables more complex reasoning than possible otherwise, and (5) enable opportunities for feedback, reflection, and revision of knowledge construction (Bransford et al., 2000). To provide visions of how this situation could improve, we offer two examples from our own research of how interfaces for immersive-mediated experiences can now shape students' learning in K-12 education.

Multi-user Virtual Environments

MUVEs can offer learning experiences intermediate in complexity between follow-the-recipe laboratory sessions and the intricacy of real world situations inaccessible to K-12 students, such as tracking the spread of a disease in a community. A project funded by the National Science Foundation to enhance middle school students' educational outcomes in science is conducting design-based research on one such MUVE-based learning experience, River City (<http://muve.gse.harvard.edu/rivercityproject/>). Students leave their classroom setting to travel through a historically accurate nineteenth century virtual city (Clarke et al., 2006). They try to figure out why people are getting sick and what actions can remove sources of illness. They talk to various residents in this simulated setting, such as children and adults who have fallen ill, hospital employees, merchants, and university scientists. Participants go to different places in the town and collect data on changes over time, acting in gradually more purposeful ways as they develop and test hypotheses. They help each other and also find experts and archives to guide them. Further, students use virtual scientific instruments, such as microscopes to test water for bacteria. This immersive simulation allows them to conduct an experiment by changing an independent variable they select, then collecting data in the city to test their hypothesis. Students not only hypothesize what would happen if a sanitation system were built – they can actually visit the city with a sanitation system added and see how this change affects the patterns of illness. To illustrate these capabilities, the following vignette portrays a student experiencing the River City MUVE as an engaging means of learning inquiry, biology, and epidemiology through collaborative mediated immersion.

Violet reenters the time portal. She looks around and sees that the rest of her classmates are filtering in behind her. She selects a date and is teleported back in time to July 1879. Violet finds herself in River City, a nineteenth-century industrial city

plagued by illness. She is standing by the train depot and starts to walk toward the hospital, the location she and her teammates have designated their meeting area. Violet sees her classmate Jabbers and waves; Jabbers waves back. Violet observes that the rain has stopped and that there is manure in the street. The streets look dirty!

Violet stops to talk to Lance Henry, a man who works in the hotel, and he tells her that it has not rained in weeks and that a summer storm was needed to wash the filth and manure out of the streets. Violet then interviews Miss Howell, another resident of River City who is on her way home from the market. Miss Howell tells her that there were not many people in the market today. Violet ponders what is keeping them away: the fear of getting sick, or all the mosquitoes and bugs. Violet records her conversations with Lance and Miss Howell in her data log. Back in April, Miss Howell complained about the mosquitoes by the bog.

This is Violet's last opportunity to collect data before developing a hypothesis. After doing exploratory research, she and her team identified that the bog was a problem. They observed many mosquitoes by the bog and were told that children who play near it have bug bites. In contrast, Violet's friend Jabber and his team identified the effluent pipe flowing into the river from the wealthy neighborhood as their problem. Violet is glad that each team gets to choose its own problem to explore, because she is interested in learning more about the mosquitoes.

During the remainder of the curriculum, Violet and her teammates will refine their hypothesis, and then design an experiment. They will visit River City two more times in order to conduct the experimental and control portions of their research method. In April, they observed the heavy rains and the run-off caused from the streets into the river. The river was overflowing, and the number of illnesses increased. They took water samples and bug counts with digital tools they brought from the twenty-first century and discovered bacteria in the water; the counts were higher by the tenements and the bog. Violet and her team also noticed that the mosquito counters were highest near the bog and dump; at that time, there were hardly any bugs by the middle of town. She is curious to see how things have changed since April.

Violet sees her teammate Ward is already at the hospital. He sees her and types, "I just spoke with Aaron Nelson; he says that things are busy. People are coming in with stomach aches, coughs, and fevers. People in the hills are sick, but they don't have upset stomachs. What do you think that means?" Violet types back that she does not know. She looks at her notes from previous visits to the city and reminds her teammates that, in April, Dr. Wright told them that a lot of the people who had stomach aches were guests at the hotel.

At that moment, Jenny arrives on the scene. The teammates divide the town into three sections. Violet wants to explore the tenements and take more water and bug samples there. Ward is interested in analyzing the hospital admissions chart and interviewing the nurses and doctors for more information on the illnesses. He wants to visit the hotel also. Jenny wants to go to the University and the wealthy home area. The three split up, sharing across distance their ongoing findings using teammate chat and virtual screenshots they can send to each other.

Two days later, Violet is back in the time portal. After working face-to-face with her teammates to develop a hypothesis and design an experiment, she is traveling

to River City to collect data. The team hypothesized: If we drain the bog, then the number of mosquitoes will go down and so will some of the illnesses, because the mosquitoes are breeding at the bog and then making people sick who are bitten. Yesterday, the team collected data on the “control” part of their experiment. They visited River City in the fall of 1879 and documented the patterns of people getting sick. There were 37 cases of upset stomach, 33 cases of fever and chills, and 22 cases of cough. The bug station readings were highest near the bog and tenements. The team interviewed many residents and collected data around their hypothesis.

Today, they are focusing on the experimental part of their experiment. Their independent variable is the bog – if the bog is drained, will the total number of illnesses go down and which symptoms of illness will decrease? The team predicted that the number of people with fever and chills will decrease because those symptoms seem to be related to spending time near the bog. The only difference between the control world they previously measured and the world they are now studying is that the bog is drained in this “experimental” world.

Violet enters at the train depot and immediately opens her clickable map, which has a flashing dot that shows her where she is standing. She clicks on the bog and is immediately teleported to it; Ward and Jenny are already there. As they walk around, the team sees the bog has vanished. Violet takes a digital picture for her virtual notebook. It’s really gone! We drained it. Let’s go find some data and see what changed.

Jabbers is sitting at the computer next to Violet. He looks at her computer screen and notices that the bog is gone in her version of River City. He turns back to his computer screen and teleports to the bog. The bog is there in his version of River City. He points to his computer screen and shows Violet. They both see that their avatars are standing by the bog; however, in Violet’s version of River City the bog has been drained, and in Jabbers’ version the bog is still there. Jabbers tells Violet to teleport to the scenic lookout where the effluent pipe is emptying into the water. Their avatars are now standing at the scenic lookout. In Jabber’s version of River City, the pipe is gone. He and his team built a water treatment station. He walks over to it in his world. In Violet’s version of River City, the pipe is still present. Violet does not have the water treatment station. Because the virtual world is a simulation, students sitting next to each other can see different worlds based on their experiment and the variable they choose to change.

Violet says that she cannot wait until the classwide research conference in two days. She is looking forward to hearing about the other teams’ experiments. She decides to go back to the control world and take a picture of the bog for before and after contrasts. Then, she will collect experimental world data to determine how draining the bog affects the illnesses in River City.

Augmented Reality

In contrast to MUVes, mediated immersion in augmented reality (AR) intertwines physical and digital contexts. Students interact with virtual people, artifacts, and experiences that are infused into real physical settings via a wireless mobile device (WMD).

Each WMD is equipped with global positioning system technology that correlates the students' real world location to their virtual location in the game's digital space. As students move through a physical location, such as their school playground or sports field, a map on their handheld displays digital objects and virtual people who exist in an AR world superimposed on the real world. Thus, AR provides collaborative mediated immersion similar to MUVES, but with different capabilities for learning.

Alien Contact! is one such AR simulation, part of a project funded by the US Department of Education Star Schools program (<http://isites.harvard.edu/icb/icb.do?keyword=harp>) designed to teach math and literacy skills to middle school students. Students work in teams of four to figure out why aliens have landed and whether they are friends or foes. Each student takes one of four roles – chemist, computer expert, linguist, or FBI agent, thus working in teams comprising the four different roles. The role of a participant determines the information and experiences provided to that learner. Each team member is given different data, and they must collaborate to solve the problems they encounter (jigsaw pedagogy). For reasons of space, we provide only a short vignette from this curriculum, now in its early stages of development, illustrating how immersive aspects of AR offer experiences different from MUVES.

As Matt and his other team members walk across the campus toward the library, he watches a dot representing his location move across the map on his handheld computer. His movement in the physical world is being tracked through a global positioning system that is synched with the virtual world in his WMD. He is walking through the campus of a local university looking for Dr. Fibonacci, a physicist who has information about why the aliens have landed. This is the team's second day collecting data. They have already talked to other witnesses and experts, including a newspaper reporter, a security guard, and a nuclear expert. He and his teammates have collected data that seem contradictory; the team is not sure whether the aliens have landed to collect uranium for dangerous purposes, have accidentally crashed on earth, or are conducting explorations prior to friendly overtures. Matt hopes that Dr. Fibonacci will provide them with more information to clarify the situation.

As Matt walks, a beeping noise indicates that he has found Dr. Fibonacci and a screen pops up on his handheld computer showing a photograph of this virtual person. Dr. Fibonacci provides Matt with evidence that the aliens may have crash landed. In his role as the chemist, he receives somewhat different data from this virtual character than does each of his teammates in the various complementary roles. In addition to interview text, Dr. Fibonacci gives Matt a document that contains a mathematics puzzle that he and his teammates must collaboratively solve. The answers to these puzzles unlock virtual evidence boxes that are located throughout the game space. These puzzles require the students to exercise mathematics and literacy skills. Matt reads through the document and then beams his ideas about solving the challenge to his teammate Rebecca, who is in charge of organizing their responses. As Rebecca puts together their answers to create the complete code necessary to unlock the box, she reads out: "1, 1, 2, 3, 5, 8, 13." Matt remembers that sequence from math class last month and exclaims, "Hey, that's the Fibonacci sequence!" The students note that there might be formulas behind all of the clues. His teammate Adam points out that

the code that unlocked an evidence box yesterday involved knowing the Pythagorean Theorem.

Matt and his team walk toward the virtual location of evidence box in a different part of the campus. As Matt walks, he periodically looks at the map on his handheld computer to see whether he is getting closer. For some reason the dot that represents him on the map is not moving toward the location of Gate 2; he starts to move in a circle watching his movement on the map. Janet, another teammate, calls out to him and points to her map: “We are walking west, but the evidence box is located toward the east near that tall building” (she points toward the building on the other side of the campus). Matt had been so excited about finding the box that he read his map incorrectly. “You’re right. Look, it is located 90° from where Dr. Fibonacci was – it is a right angle. Let’s go.” As he approaches the coordinates of the evidence box, a screen flashes on his handheld device asking for the secret code. He types in the sequence, and the box in the virtual world opens. Inside are alien documents and artifacts that contain data around the problem. Matt examines a document about uranium that is hard to decipher because the aliens have encoded it linguistically and mathematically. As the chemist on the team, Matt has collected a lot of data about uranium; as best he can tell, this document seems to provide more information about its various uses beyond nuclear weapons. He records notes in his data log and beams them to each of his teammates.

These vignettes contrast how MUEs empower creating contexts inaccessible in the real world while AR enables the infusion of virtual contexts within physical locations. In both MUEs and AR, knowledge is grounded in a setting and distributed across a community, rather than isolated within individuals. As a result, collaborative interpretation of complex experiences becomes central to learning. Contrary to conventional K-12 instruction where knowledge is decontextualized and explicit, in MUEs and AR the learning is situated and tacit: Problem-finding is central to problem-solving. This parallels the nature of twenty-first century work, as well as the learning styles and strengths of today’s digital-age students.

Conclusion

Emerging interfaces for collaborative, mediated immersion are shaping the types of skills and knowledge society values, the ways people can learn, and the characteristics of individual students (Dede, 2005). To better prepare students for the future, we need to integrate these emerging technological interfaces into instructional design and pedagogical practices. In order for students to compete in the emerging, global, knowledge-based workplace, they need appropriate knowledge and skills: media and information literacy; the ability to think critically, recognizing and solving complex problems; effective communication and collaboration skills, both face to face and across distance; and creativity (Anderson, 2008; Partnership for 21st Century Skills, 2004; Lemke, 2001). MUE and AR interfaces, while not the only ways to provide students with these skills, have the advantage of situating learning experiences in collaborative, mediated, immersive educational environments comprising multiple

learning modalities. Using these interfaces creates a shift in how students participate in educational practices, which in turn shapes their identities as learners (including their engagement and beliefs about their abilities to learn (Greeno, 1997; Wenger, 1998). Enabling multiple learning modalities ensures that students are being taught in ways that reflect their learning styles – fostering success for the many students who do not perform well in traditional classroom instruction. For example, research on River City has found that students who do not perform well in traditional instructional settings do well in River City (Clarke, 2006; Ketelhut et al., in press-a, in press-b). Further, engaging in learning that is situated in authentic contexts and is motivating for students may empower transfer of academic learning to real world contexts and situations.

Research on MUVE and AR environments is in its infancy, yet we believe studying these interfaces may deepen scholars' and practitioners' understandings of how different learning modalities shape learning and as a result offer new opportunities for assessment. While we outlined the above-mentioned scenarios in the context for learning, we envision immersive simulations being designed for the purpose of assessing student learning on such skills as inquiry, problem-solving, and complex-reasoning. We hypothesize that various students will perform better using different variations of these interfaces or combinations of learning modalities – one size will not fit all. If we can identify through research how individual student characteristics shape that person's learning under various instructional conditions, then we can better customize teaching to individual needs.

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