Multi-User Virtual Environments for Teaching and Learning

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INTRODUCTION

In the late 1970s, Richard Bartle and Roy Trubshaw of the University of Essex developed the first MUD (Multi-User Dungeon/Domain/Dimension, depending on the source) to facilitate multi-player role-playing games run over computer networks (Bartle, 1999; Dourish, 1998), allowing groups of individuals to build virtual realities collaboratively. Despite limited visual and social cues, immersion in text-based virtual environments have the capacity to support thriving virtual communities that demonstrate characteristics of traditional communities, such as love, hate, friendship, and betrayal (Rheingold, 1993).

Advances in computational power and network connectivity have driven the evolution of MUDs, resulting in diverse human computer interfaces such as MOOs (object-oriented MUDs), MUVEs (multi-user virtual environments), and MMORPGs (massively-multiplayer online role-playing games), among others. The present article focuses primarily on MUVEs.

Although MUVEs are commonplace to gamers (i.e., players of *EverQuest*, *Doom*, and *Madden NFL*), the affordances of this interface are rarely utilized for substantive teaching and learning. This article will discuss how MUVEs can be used to support the situated and distributed nature of cognition within an immersive, psychosocial context. After summarizing significant educational MUVEs, we present Harvard University's River City MUVE (http://muve.gse.harvard.edu/rivercityproject) in depth as an illustrative case study.

BACKGROUND

MUVEs have been used in education for:

- creating online communities for pre-service teacher training and in-service professional development (Bull, Bull, & Kajder, 2004; Riedl, Bronack, & Tashner, 2005; Schlager, Fusco, & Schank, 2002),
- engaging science-based activities while promoting socially responsive behavior (Kafai, 2006),
- helping students understand and experience history by immersing them emotionally and politically in a historical context (Squire & Jenkins, 2003),
- promoting social and moral development via cultures of enrichment (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005),
- providing an environment for programming and collaboration (Bruckman, 1997),
- creatively exploring new mathematical concepts (Elliott, 2005), and
- engaging in scientific inquiry (Clarke, Dede, Ketelhut, & Nelson, 2006; Ketelhut, Dede, Clarke, Nelson, & Bowman, in press).

Regardless of content and intended user group, all MUVEs enable multiple simultaneous participants to (a) access virtual contexts, (b) interact with digital artifacts, (c) represent themselves through "avatars" (in some cases graphical and in others, text-based), (d) communicate with other participants (in some cases also with computer-based agents), and (e) take part in experiences incorporating modeling and mentoring about problems similar to those in real world contexts (Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004). Table 1 summarizes

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significant educational MUVEs active in the past few years, their learning goals, their features and capacities, and their corresponding URLs.

Table 1 Summary of Educational MUVEs, Learning Goals, Functionality, and Corresponding URLs

MUVE	Developer	Learning Goals and Objectives	Functionality	Website
AppEdTech	Appalachian State University	Distance education courses and services for graduate students	AppEdTech is a graphical MUVE designed to support graduate students working over distance. Student control avatars that interact with other students, instructors, and artifacts, such as course resources.	http://www.lesn.appstate.edu/aet/aet.htm
AquaMOOSE 3D	Georgia Institute of Technology	Visualization of and experimentation on parametric equations	AquaMOOSE 3D is a graphical MUVE designed for the construction and investigation of parametric equations.	http://www.cc.gatech.edu/elc/aquamoose
MOOSE Crossing	Georgia Institute of Technology	Computer programming and collaboration	MOOSE Crossing is a text-based MUVE designed for kids aged 9-13. Through the interface, users create virtual objects, spaces, and characters, while interacting with one another through text.	http://www.cc.gatech.edu/elc/moose-crossing
Quest Atlantis (QA)	Indiana University	Promotion of social and moral development	QA is a graphical MUVE designed for children ages 9-12 to complete activities with social and academic merit in both formal and informal learning settings.	http://atlantis.crlt.indiana.edu
Revolution	Massachusetts Institute of Technology	History	Revolution is a multiplayer role playing game where students experience history and the American Revolution by participating in a virtual community set in Williamsburg, VA on the eve of the American Revolution.	http://educationarcade.org/revolution
River City	Harvard University	Scientific inquiry and 21st century skills	River City is designed for use in middle school science classrooms. As visitors to River City, students travel back in time, bringing their 21st century skills and technology to address 19th century problems.	http://muve.gse.harvard.edu/rivercityproject
Tapped IN	SRI	Online teacher professional development	TI bundles synchronous and asynchronous discussion tools, a notes section, an interactive whiteboard, and file sharing space. After logging into the virtual space, users are teleported to the TI Reception Area and greeted by Helpdesk staff.	http://tappedin.org
Whyville	Numedeon, Inc	Scientific literacy and socially responsible behavior	Whyville is a graphical MUVE designed for children between middle childhood and adolescence. Whyville users, called citizens, from all over the world access Whyville through a web-based interface to (a) communicate with old friends and familiar faces through synchronous chat and the *Whyville-Times* (Whyville's official newspaper with article written by citizens), (b) learn math, science, and history through interactive activities, and (c) build online identities. As citizens participate in a variety of activities, they earn clams (the official monetary unit of Whyville), which they can use to enhance their avatars and throw parties.	http://www.whyville.net

In the interest of space, we offer River City as an illustrative case study of how a MUVE can be designed to support the situated and distributed nature of learning, thinking, and activity. Although the examples provided below are primarily related to River City, the explanations of functionality and capabilities in relation to theories of learning are common among the MUVEs described previously.

River City is a MUVE for teaching scientific inquiry and 21st-century skills in middle school science classes. Drawn from the National Science Standards (National Research Council, 1996), River City is designed around topics that are central to biological and epidemiological subject matter. As visitors to River City, students travel back in time, bringing their 21st-century knowledge and technology to address 19th-century problems. River City is a town besieged with health problems, and students work together in small research teams to help the town understand why residents are becoming ill. The River City MUVE features an underlying simulation that allows students to manipulate variables to help determine the cause of the epidemic. Students collect data, form hypotheses, develop controlled experiments to test their hypotheses, and make recommendations based on their findings to other members of their research community.

ADVANCES IN THE SCIENCE OF HOW PEOPLE LEARN

Parallel to the technological and networking developments necessary to produce MUVEs are the psychological frameworks needed to understand their impact on cognition. Recent advances in the science of how people learn consider the situated and distributed nature of cognition as applied to thinking, learning, and doing in workplace and community settings (Chaiklin & Lave, 1993; Engeström & Middleton, 1996; Hutchins, 1995; Wenger, 1998). Cognition is viewed as situated within both a physical and a psychosocial context and as distributed between a person and his or her tools (Barab & Plucker, 2002; National Research Council, 2000a; Sternberg & Preiss, 2005). Although distributed cognition and situated learning are treated separately, the relationship between the two perspectives is complementary and reciprocal.

MUVES AND DISTRIBUTED COGNITION

From a distributed perspective, cognitive processes — perception, learning, reasoning, and memory — are no longer confined within the head of an individual (Hutchins, 1995; Salomon, 1993). “A process is not cognitive simply because it happens in a brain,” as Hollan, Hutchins, and Kirsh (2000) argue, “nor is a process noncognitive simply because it happens in the interactions among many brains” (p. 175). Advances in the science of distributed cognition have come to include cognitive activity that is distributed across internal human minds, external cognitive artifacts, groups of people, and space and time (e.g., Zhang & Patel, 2006). Viewing the same criteria through a lens of educational practice, the mental burdens of activity can be understood as dispersed physically, socially, and symbolically between individuals and the tools they are using (Pea, 1993; Perkins, 1993). Considering each of these three aspects of distribution, we can better understand the affordances of MUVEs.

Physical Distribution of Cognition

When a student works with her notebook to prepare a portfolio of her work, “the notebook is both an arena of thinking and a container of learning” (Perkins, 1992, p. 135). The notes, assignments, and essays represent a physical distribution of learning, reasoning, and memory between the author and her notebook. The cognition neither resides solely in her head nor in her book, but instead is distributed between the two entities.

For example, students in River City use a laboratory notebook as the primary resource to navigate the 3-D environment and guide them through the curriculum. To overcome the limited amount of information that can be processed in any one place before exceeding what the student is capable of processing on his or her own, the notebook is paper-based to allow for the physical distribution of memory and information processing among the student, the simulation, and the notebook. Additional examples of the physical distribution of cognition within the River City simulation include (a) an online notepad that students use to record fieldnotes, track data on change over time, and record answers and reflections guided by the Laboratory Notebook; (b) authentic scientific tools such as an online microscope, bug catcher, and environmental health meter; (c) an interactive map of the town; and (d) digitalized Smithsonian artifacts.

Social Distribution of Cognition

A prerequisite of the social distribution of cognition is the physical distribution of cognition (Perkins, 1992). For example, jigsaw pedagogies typically rely on students individually mastering one type of knowledge through various experiences and tools, taking advantage of the physical distribution of cognition, and then working with other learners to apply complementary forms of expertise in order to understand a complex phenomenon (Aronson & Patnoe, 1997; Johnson & Johnson, 1999). Through the collaborative experiences of teaching and learning from other students and virtual agents in the world, students distribute cognition socially.

By design, the phenomena students investigate in River City are too complex for any one student to master within the time allotted for the project. Central to the River City experience is the social distribution of perception, learning, and reasoning through the affordances of the simulation and within various group activities. Although students see the avatars of other users participating in the simulation, communication is deliberately constrained by the technology so that students can interact only with members of their team and residents of River City.

After teams of students have worked through a range of preliminary activities (e.g., learning to use the tools of scientists), they construct an experiment that tests their ideas about why people are getting sick in River City. The experimental process is designed to help students come to consensus on what is to be tested and how best to test it. Even though students in the same class will have completed the same preliminary activities, different groups will choose to investigate different problems.

Students then enter a control world in the simulation, select the independent variable the team has agreed to investigate, and focus on collecting only the data needed to test their hypothesis. Afterward, they enter an experimental world, which is identical to the control world except for the characteristics associated with their chosen independent variable. Collecting data using the same techniques and from the same sources in the control and experimental worlds, teams of students are equipped with a dataset they can use to test their hypothesis and formulate conclusions based on empirical data.

At the end of the project, the whole class convenes a research conference so that student-groups can share and discuss their results. Similar to the complexities of studying real world phenomena, not all teams of students will arrive at the same conclusions, even when provided the same initial conditions. Through the social distribution of cognition among the whole class, variations among conclusions help students to begin to learn that the world is a complex place in which multiple perspectives exist and "truth" is often a matter of evidentiary interpretation and point-of-view.

Symbolic Distribution of Cognition

The physical and social distribution of cognition often engenders symbolic distribution of cognition through various symbol systems, such as mathematical equations, the specialized vocabulary having to do with a field of work, and representational diagrams (Perkins, 1992). Concept maps, for example, transform thoughts and notions into tangible symbols where nodes (i.e., bubbles) represent concepts and propositions (i.e., connecting words) that act as logical bridges between concepts (Novak, 1998; Novak & Gowin, 1984). Common uses of concept maps for teaching and learning include advanced graphical organizers (Willerman & MacHarg, 1991), tools for collaborative knowledge construction (Roth & Roychoudhury, 1993), and assessment instruments (McClure, Sonak, & Suen, 1999).

A barrier to symbolic distribution of cognition in classrooms, as Perkins (1992) has argued, is the dearth of language for thinking and a need to "cultivate a common vocabulary about inquiry, explanation, argument, and problem solving" (p. 143). To overcome this barrier, students in the River City project learn and use the specialized language, customs, and culture of the scientific community. For example, at the end of the River City project, students complete a performance assessment that allows them to demonstrate their understanding of scientific inquiry and disease transmission by independently writing evidence-based letters to the Mayor of River City. Using the language of science and scientists, the students offer their explanations for why so many residents are becoming ill.

An additional example of symbolic distribution of cognition characteristic of all MUVEs is the user's avatar: the virtual, symbolic, embodiment of the user within the virtual space. Depending on the MUVE, the avatar is either graphical or text-based. Expressions, gestures, facial expressions, clothing, and other symbols or symbolisms that are used to define identity in face-to-face settings are virtually created and projected by participants in MUVEs; they define who (or what) the participants want to be. As Turkle (1995) observed, participation in such environments provides the user with the ability to create one or multiple online identities, which allows him or her to explore how an individual is recognized or known.

MUVES AND SITUATED COGNITION

Central to the situated perspective of cognition is the study of learning as a phenomenon that occurs in the course of participation in social contexts. Concepts are not considered independent entities, void of the activities and cultures in which they exist (Brown, Collins, & Duguid, 1989). Instead, activity, concept, and culture are entwined among the physical and social contexts for knowing and understanding. Knowing, as Barab and Duffy (2000) argue from the situated perspective, is (a) an activity, not a thing; (b) always contextualized, not an abstraction; (c) reciprocally constructed between an individual and his or her environment, not as an interaction defined objectively or created subjectively; and (d) a functional stance based on interaction and situation, not a "truth."

Through an apprenticeship, for example, a person works with a master artisan to learn a trade or craft. Apprenticeship, by its very nature, incorporates learning within a specialized social context. Drawing on the strengths of the traditional apprenticeship model, Collins, Brown, and Newman (1989) conceived of *cognitive apprenticeships* as a three-part sequence of modeling, coaching, and fading. The apprentice first observes the master modeling a targeted task. Next, the master coaches the apprentice as he or she attempts to complete the same task, providing scaffolds when and where appropriate. As the apprentice becomes adept at the task, the master's presence fades to providing just-in-time support when needed.

Within the River City simulation, students take part in cognitive apprenticeships in two ways: first when they interact with virtual agents at River City University, and second through their ongoing dialogue with a virtual investigative reporter. At the university, students experience expert modeling of scientific processes and inquiry by collaborating with university professors and graduate students. For example, Ellen Swallow Richards (an historic figure who was the first woman to graduate in chemistry from MIT) is a professor and researcher at River City University who gives lectures about her research and connects it to the steps of the scientific method. Students participating in the simulation listen to Professor Richards' lectures to become versed in the scientific method. In addition to learning about Dr. Richard's research, students also interact with graduate students who discuss not only how to conduct research through books in the library, but also how to identify problems in River City and generate testable questions. These interactions model for students scientific processes as they are experiencing them in their own research in River City.

Students are given a second opportunity for apprenticeship through their interaction with Kent Brock, an investigative reporter who is symbolic of the wise fool — someone who asks obvious questions that brings about reflection and reexamination of beliefs or understandings. On the one hand, Kent interviews students to find out what they know and how they are making meaning of their experiences. As a good reporter, he is concerned in more than just the facts, asking students to explain, interpret, and apply what they are learning, as well as to empathize with residents and to engage in metacognition about their ideas (based on Wiggins & McTighe, 2005). On the other hand, Kent provides students with information to make sure they have interviewed important residents and accessed significant tools and artifacts.

Going beyond learning-by-doing, while immersed in the social context of acting as scientists students participate in what Lave and Wenger (1991) describe as "legitimate peripheral participation." Students surpass examining the concepts of science and instead *learn about science by being scientists*. Instead of *being talked to* by those who are more expert, the affordances of the River City curriculum supports students as they *begin talking within* the community of scientists, a key to legitimate peripheral participation (ibid). Through immersion of the simulation and engagement with authentic tasks, students *begin to become scientists* as they (a) learn the principles and concepts of science, (b) acquire the reasoning and procedural skills of scientists, (c) devise and carry out investigations that test their ideas; and (d) understand why such investigations are uniquely powerful (National Research Council, 2000b). This active participation acts as a vehicle for capturing the progression by which "newcomers become part of a community of practice. A person's intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a sociocultural practice" (Lave & Wenger, op. cit., p. 29).

FUTURE TRENDS

Sheingold and Frederiksen (1994) have noted that, “to change our expectations about what students should know and be able to do will involve also changing both the standards by which student achievements are judged and the methods by which student’s accomplishments are assessed” (p. 111). MUVEs are a technology-based innovation that (a) changes both what and how students learn and teachers teach and (b) lends itself to capturing student learning.

Changing Teaching and Learning

A primary reason for studying and developing MUVEs, such as River City, is their ability to leverage aspects of authentic learning conditions that are hard to cultivate in traditional classroom settings (Griffin, 1995). In addition to creating experiences that take advantage of the situated and distributed nature of cognition, MUVEs also allow for the design of situations that are not possible or practical in the real world. Through the affordances of a MUVE, researchers and designers can create scenarios with real-world verisimilitude that are safe, cost effective, and directly target learning goals.

MUVEs for Assessment

Limitations of traditional classroom practices make it impossible to monitor and track what every student is doing, leaving educators unsure of what students have (or have not) learned. Facial expressions, shows of hands, and cold-calling individual students are tacit ways of calibrating the learning taking place in a classroom; but they fail to capture the efforts of every student. Future trends in MUVE research include establishing efficient and effective mechanisms for capturing and processing what students know and are able to do.

The River City simulation’s connection to databases enables the system to capture and record every action made in the River City simulation. For example, students record their answers from the Laboratory Notebook in an online notepad and use a synchronous text-based tool to communicate with teammates and residents, both of which are captured and processed by the database. This data, which is emailed to teachers within 24-hours, provides educators formative assessments of student learning and enables them to track individual student progress over time. Teachers can detect early on if students fall off-task or need review of specific concepts. This information also provides teachers snapshots of student learning that they can share with students, administrators, and parents.

CONCLUSION

Coupled with technological advances are the cultures that evolve with them. In the three decades since the first text-based MUDs were conceptualized on college campuses, their successors have become a major force, shaping how we communicate, participate, learn, and identify ourselves. Despite the MUVE interface and its influence on how people learn outside of classrooms, teaching practices have not changed to embrace such technologies. Although 20 years old, Resnick’s (1987) observations about schools are still generally accurate. Whereas schools focus on individual performance, unaided thinking (i.e., thinking without tools, prompts, etc.), symbolic thinking (i.e., thinking with abstract representations, rather than more concrete terms related to particular situations), and general skills, cognition outside of schools is usually socially distributed and tool use is prominent, involving the particularization and contextualization of abstractions, and learning that tends to focus on situation-specific ideas.

We recognize that the best learning environments for students are those that are authentic, situated, and distributed across internal and external sources. Yet these conditions are often difficult to create in classroom settings. MUVEs open up a new world of possibilities for creating learning experiences that not only are authentic, situated, and distributed, but also provide a context to change our standards by which student achievements are judged and the methods by which students' accomplishments are assessed (Sheingold & Frederiksen, op. cit.).

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KEY TERMS AND THEIR DEFINITIONS

Avatar — the dynamic, virtual embodiment of a user while he or she is within a virtual space
Distributed Cognition — the scientific study of cognition as it is distributed across internal human minds, external cognitive artifacts, groups of people, and space and time
MUD — a virtual environment that supports the simultaneous participation of multiple users in a text-based game
MUVE — multi-user virtual environments that enable multiple simultaneous participants to (a) access virtual contexts, (b) interact with digital artifacts, (c) represent themselves through "avatars", (d) communicate with other participants, and (e) take part in experiences incorporating modeling and mentoring about problems similar to those in real world contexts
Physical Distribution of Cognition — a distribution of learning, reasoning, and memory between an individual and his or her tools, objects, and surround
Situated Cognition — the scientific study of cognition as a phenomenon that occurs in the course of participation in social contexts

Social Distribution of Cognition — distribution of cognition through teaching and learning among individuals in collaborative environments
Symbolic Distribution of Cognition — distribution of cognition through symbol systems such as mathematical equations, the specialized vocabulary having to do with a field of work, and representational diagrams
Virtual Agents — a program, often represented as a person or animal, whose automated interactions provide the semblance dialogue