3D Multi-User Virtual Environments: Promising Directions for Science Education

Centered on the theme of scientific inquiry, this article describes a number of 3D multi-user virtual environment programs and their potential for improving science learning.

Our nation's students fall short in science. The Department of Education's 2000 National Assessment of Education Progress (NAEP), also known as "The Nation's Report Card," showed no improvement in student science performance between 1996 and 2000 in grades four and eight, and a slight decline in performance by twelfth-graders. While results from the 2005 NEAP indicated improvement for elementary school students in science achievement over the last decade, middle school scores have remained flat, and high school scores have continued to decline since 1996, in sharp contrast to the large gains in math, and slower but still significant gains in reading (National Assessment of Educational Progress, 2005). A recent report from the National Center for Education Statistics revealed that American students scored below average on science literacy in the 2006 Program for International Student Assessment (PISA), trailing their peers in 16 of 30 industrialized countries (National Center for Education Statistics, 2007).

Lamenting the "statistically and morally significant" fall in science results, Rod Paige, former Education Secretary, warned that "(e)veryone should be concerned—82% of our high school seniors are not performing at the proficient level in science," (Leath, 2001) which could threaten the country's economic future and damage national security in the long run. In reaction to U.S. students' science performance in 2006 PISA, Senta Raizen, Director of WestEd's National Center for Improving Science Education, pointed out that U.S. students "seem to lack a strong grasp of the nature of science, and of science's important role in society" (Cavanagh, 2007).

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What obstacles have hindered U.S. students' performance in science? While studies have identified a number of factors that have contributed to the decline of science education, such as shortage of highly qualified teachers and inadequate support from the public system and community, two pressing issues are in need of a rapid response. First, compared to reading and math, which by law are the nation's educational priority, much less attention and thus relatively limited time are devoted to science teaching, especially in elementary schools. The results of the *National Survey of Science and Mathematics Education: Trends from 1977 to 2000* showed that, while mathematics continues to be taught virtually every day in grades 1-12, only about 70 percent of elementary classrooms receive science instruction every day (Smith, Banilower, McMahon, & Weiss, 2002). A more recent study investigated the status of science education in California Bay Area elementary schools, which is home to much U.S. innovation in science and technology, but which ranked 2nd lowest of all states in 2005 NAEP in science. This study showed a diminishing amount of time spent on science since the enactment of No Child Left Behind, and schools in program improvement status reported that little to no time was being spent on science at all because of their need to show improvements in the tested subjects of language arts and mathematics (Dorph, Goldstein, Lee, Lepori, Schneider, & Venkatesan, 2007).

Parallel to the time constraints, the dominant science instruction pedagogy is problematic. Heavily influenced by the high-stake tests and standards-based curriculum and exacerbated by time constraints, science teachers have focused primarily on delivering the outcomes of science to their students, as opposed to engaging them in the inquiry process. This deviates from the nature of science learning. Compared to their peers in high-achieving countries (such as Japan, Australia, and the Netherlands), U.S. science teachers tend to present science content as a collection of discrete facts, definitions, and algorithms rather than as a connected set of ideas, and high-interest activities and real-life issues are usually designed and introduced as a side-bar to motivate and engage students, rather than being used as tools for developing concepts (Roth & Garnier, 2007). The National Science Education Standards emphasize that scientific inquiry is at the heart of science and science education (National Research Council, 1996); the National Science Teachers Association (2004) suggests that all K-16 teachers embrace scientific inquiry. Although inquiry has a decade-long history of strongly supported recommendation as a best practice in science education, its implementation in the classroom is, unfortunately, misguided. Many teachers, unclear about how to implement inquiry in the classroom, substitute real scientific inquiry with traditional "cookbook" experiments (Wallace & Louden, 2002).

Exemplary 3D Multi-User Virtual Environments for Science Education

Leveraged by federal support to address the critical crisis in science education, scientists, science education researchers, and school teachers have started to join efforts to explore how to maximize the use of emerging technologies to improve science teaching and learning. There has been a surge of interest in the use of emerging 3 dimensional (3D) multi-user virtual environment (MUVE) technology to engage and motivate learners, support authentic scientific inquiry, and facilitate students' construction of science knowledge and development of inquiry skills in a socially situated and distributed environment. Made popular by SecondLife, the 3D MUVE is an immersive 3D virtual space where people, entering the space via avatars, meet and interact with one another and learn in the multi-user environment in real time. A variety of 3D MUVE programs has rapidly burst into the limelight in science education, including Harvard University's River City, Indiana University's Quest Atlantis, Cornell University's SciCentr, and North Dakota State University's Geology Explorer and Virtual Cell.

River City

River City, funded by the National Science Foundation and developed by the Graduate School of Education at Harvard University, is a scientific inquiry-based 3D MUVE that targets middle school students. Adopting a storyline—a familiar game design scheme among mainstream games—River City is set in a 19th-century city with a river running through it, and its citizens face a chronic illness. The students' task is to find out why the residents of River City are getting sick and what can be done to help them. The problems are interdisciplinary and integrate aspects of science, history, and social studies, allowing students to experience real world inquiry skills that are required when disentangling multi-causal problems in a complex environment.

Centered on the scientific inquiry skills and on the content in biology and ecology that are embedded within historical, social, and geographical contexts, River City guides students through making observations, posing questions, developing hypotheses, investigating, explaining, predicting, proposing answers, and communicating the results in the form of a letter to the Mayor of River City. River City has been implemented successfully in twelve states in the U.S., and has involved approximately 100 teachers and over 5,000 students in 2007-2008 (Harvard University, 2008).

Quest Atlantis

Quest Atlantis, funded by the National Science Foundation and MacArthur Foundation and developed by the Center for Research on Learning & Technology at Indiana University, is another widely cited innovative science learning program. Similar to River City, Quest Atlantis is a 3D multi-user online learning community intended to engage children ages 9-12 in science learning. Its legend is that the people of "Atlantis" face an impending disaster; their world is slowly being destroyed through environmental, moral, and social decay. The task of the project is to save Atlantis. Leveraging 3D technologies and game-based methodologies, the problems are presented in an interactive narrative in which the "reader" has agency in co-determining how the story unfolds (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007).

To echo the national call for inquiry-based math and science learning, Quest Atlantis has been designed to support children's learning and thinking through the use of scientific inquiry. Its inquiry-based activities begin with an interesting problem that is grounded in real-world issues. Students are involved in refining questions, gathering data, evaluating information, developing plausible interpretations, and reflecting on their findings. Similar to other multi-user virtual worlds, Quest Atlantis is a globally distributed community with more than 20,000 participants from four continents (Barab, Arici, & Jackson, 2005).

SciCentr

SciCentr, an outreach program of Cornell University's Cornell Theory Center, is a 3D multi-user chat-enabled online museum developed to engage young people in science, technology, engineering, and mathematics subjects. As opposed to River City and Quest Atlantis, which focus on the guided inquiry method of learning, SciCentr is based on constructivism in that it promotes children's exploration of scientific topics of their own choice and provides a virtual platform for them to share their passion and knowledge of a particular topic with the science community.

Since 2001, SciFair, a portion of the online SciCentr museum, has involved more than 1,000 middle school students and teachers annually. Participants build their own virtual knowledge spaces that combine science exhibitions with game interactions. SciFair was designed to target a wide variety of settings, especially in terms of cultural diversity, that include underserved, rural, and minority communities. For example, SciFair has been successfully implemented as a science communication program with Native American students in Washington and urban middle school students in New York and Virginia (Corbit, Bernstein, Kolodziej, & McIntyre, 2006).

Geology Explorer and Virtual Cell

Developed by North Dakota State University's World Wide Web Instructional Committee, Geology Explorer is a multi-user role-playing virtual environment that provides secondary and post-secondary students the means and equipment to carry out geologic investigation of a mythical planet called "Planet Oit". This planet is described as similar to Earth, but it is directly opposite of the Sun from Earth. In a role-based "learn by doing" environment, students take on the role of a geologist and learn fundamental concepts of geology and inquiry strategies used by geologists through exploration, experimentation, and guided collaboration.

Along with Geology Explorer, Virtual Cell is a similar 3D MUVE for learning fundamental concepts of cell biology and strategies for diagnostic problem-solving. Similar to Geology Explorer, the pedagogical approaches are to provide students with authentic problem solving experiences that include elements of practical experimental design and decision making, while learning science content at the same time (Slator & Beckwith, 2006). These two programs have significantly facilitated science students' learning of abstract concepts in geology and cell biology via 3D visualization and modeling.

Promising Directions for Science Education

As evidenced in these pioneering 3D MUVE programs for science education, this emerging technology holds great promise and opportunities for improving science learning and is potentially a viable solution to the pressing issues facing science education in schools.

1. Platform for Scientific Inquiry

The 3D MUVE provides a viable platform to support the authentic scientific inquiry process and help learners acquire inquiry skills defined by the National Science Education Standards (1996). As in River City and Quest Atlantis, the scientific inquiry process and skills are seamlessly embedded in the immersive probing environments. In such environments, students are first exposed to a complex, authentic problem, such as finding solutions to save Atlantis from problems similar to those being faced on Earth. In order to disentangle the complex multi-causal problems, students need to go through the process of making observations, refining questions, gathering data, evaluating information, developing plausible interpretations, and reflecting on their findings—a set of inquiry activities that are at the heart of science and science education. Additionally, the science content and skills specified in the curriculum are embedded in the inquiry activities, which provides an opportunity for the assessment of students' mastery of these contents and skills.

The unique technological affordances of 3D MUVE offer a variety of tools for conducting scientific inquiry. One of 3D MUVE's salient features is its ability to construct a virtual space that can not only resemble but go beyond the real world, and provide an experience that is not accessible, possible, or practical in reality. In Geology Explorer, for example, students are able to access and examine almost 100 different rocks and minerals that are normally not readily available, and use nearly 40 scientific instruments and geology tools (e.g., "streak," "scratch," "hit," "view," "taste," and "touch," etc). This greatly enhances students' inquiry experiences by providing exploration opportunities similar to those of a real geologist. In addition, in most 3D MUVEs, students can teleport instantly from one place to another, "physically" (via avatar) visiting a place thousands of miles away or even on the other side of the globe and meeting and chatting with people and content experts from around the world. These capabilities can create a profound sense of motivation and engagement conducive to a rich and deep inquiry experience.

2. Gateway to Engaged Learning

Our schools are faced with the challenge of engaging this generation of students in formal learning in the classroom. Studies over a span of two decades reveal a consistently low level of engagement in the classroom, which has resulted in widely reported boredom and an escalated high school drop-out rate. One reason may be related to the widening gap between the tech-savvy students and the print-centric schools. Children today are growing up in a rapidly evolving digital media environment where using cutting-edge gadgets has become an integral and important part of their growing and learning experience. Despite children's massive use of digital technologies outside of the classroom, schools still continue to operate within a print-based cultural logic.

Yet as revealed by studies on the above-discussed programs, the 3D MUVE is a motivationally rich gadget that deeply engages students in an enjoyable and fervent game-like environment. Results from the implementations of River City in public school classrooms indicate that students, both boys and girls, are highly motivated by the 3D MUVE program, with students reporting that they "felt like a scientist for the first time" (Clarke & Dede, 2004). Similarly, students in SciCentr rate their learning experience in 3D MUVE significantly higher than in a traditional science teaching environment, stating that they have more fun and have learned more (Norton, Corbit, & Ormaechea, 2008). Moreover, SciCentr appears to have the greatest impact on students who begin with neutral or negative attitudes toward science. This echoes the results of River City, which showed a greater impact on learning for low achieving students in inner-city schools (Dede & Ketelhut, 2003). These findings make it obvious that, if well designed and wisely used, the 3D MUVE would be a viable platform to increase student engagement, which is important to students' achievement and to their social and cognitive development.

3. Bridge between Formal and Informal Science Learning

As discussed previously, science learning in a school setting is subject to time constraints, in addition to the added complexity of classroom management introduced by technology. The 3D MUVE appears to be an ideal supplemental tool that connects formal science learning in class and learning in an informal setting, such as after-school programs, or leisure time playing at home. A consistent theme among the existing 3D MUVE science programs is that they are being implemented with great success in the informal setting, as teaching aids or supplemental activities in K-12 science classes.

Except for the above mentioned exemplary 3D MUVE science programs, there have been few efforts to leverage the energy, passion, and engagement children show for the 3D game world in their time outside of school. Children's enthusiasm with 3D MUVE should be harnessed and linked to the science content and inquiry skills required in the curriculum. Instead of grousing and competing with reading and math for a share of the limited amount of time available in school, science educators should make the most of the 3D MUVE's abundant features and popularity, and connect it with in-school activities. By building a continuum between classroom instruction and after-school or at-home activities in 3D MUVE, the passion and informal learning that occur in the 3D game-playing environment will transfer into the classroom and significantly increase student engagement in the formal learning setting.

Conclusions

The fact that it is a multi-billion dollar industry that rivals Hollywood's cultural influence shows that digital games are now a dominant play culture, and they are increasingly affecting kids' development and informal learning outside school. It is becoming ever more evident that technologies make access to children's interests, passion, and preferred learning styles quick and easy. To harness the power of 3D MUVE and leverage the passion and energy children have with this media, schools need to consider seriously the role of 3D MUVE in science education. As we have seen in the pioneering 3D MUVE science programs designed by forward-thinking science education researchers, the 3D MUVE definitely holds great potential and opportunities for improving science learning and points to a new, promising direction for science education. It is a viable platform for conducting scientific inquiry, a gateway to an engaging, socially distributed learning environment, and a bridge to connect and blend formal and informal science learning. After efforts of more than a decade in science education reform with marginal results, it may be time to sit down and watch how our children play and learn with the new media, experience their enthusiasm and creativity in the digital world, and ask ourselves how we can make this happen in the classroom.

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