Chapter 4.16
Effects of Teaching Science Through Immersive Virtual Environments

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ABSTRACT

The North Dakota State University (NDSU) World Wide Web Instructional Committee (WWWIC) is an inter-disciplinary research team, which has, since the 1990s, developed multi-user, interactive virtual environments (IVEs) to teach the structure and process of various branches of science. The most developed of these include the "Geology Explorer" and the "Virtual Cell," (VCell). This chapter describes the key features the Virtual Cell and the Geology Explorer, the underlying philosophy and educational theory guiding their development, and results of large controlled experiments that investigate their effectiveness on student learning. Additionally, ongoing projects and experiments of the team relevant to the development and dissemination of these software programs are explored. The underlying purpose of our IVEs is to increase student achievement and scientific problem-solving skills while providing students with opportunities to learn-by-doing in a real-world context. Research findings collected for almost a decade demonstrate the positive impact of our IVEs on science students.

INTRODUCTION

Immersive virtual environments (IVEs) offer a computer-based method for science instruction that provides a number of advantages over traditional instruction. Students are invited into simulated worlds that offer interactivity, authentic experiences, and, in the best cases, an adventure in learning. The World Wide Web Instructional Committee (WWWIC) at North Dakota State University (NDSU) has been researching and developing IVE systems of this sort since the 1990s.

The most developed of these include the "Virtual Cell," (VCell)(White, McClean, & Slator, 1999) where students enter into a 3D cell simulation and perform experiments on various biological functions, and the "Geology Explorer" (Schwert, Slator, & Saini-Eidukat, 1999) where students land on a foreign planet and perform geologic tests while exploring the environment.

Each of these IVEs has been used in college-level courses at multiple universities where they were rigorously studied regarding their effectiveness on student learning, both in content knowledge and problem-solving skills. Results consistently indicate that IVE students perform higher on various assessments than their counterparts in a traditional setting. Further, there is anecdotal evidence that IVE students enjoy the learning more. While collecting and analyzing data on student learning, WWWIC has continued to evaluate the IVEs and improve their effectiveness using standard software evaluation procedures. As a result, both programs have continued to evolve and have a range of modules planned and under development.

More recent WWWIC projects include the development of both 2-dimensional and 3-dimensional world building, teacher assistance Web pages for module development, and the inclusion of many new modules for teaching students a broader range of topics within each of the virtual worlds.

Technically speaking, WWWIC simulations are hosted on a LambdaMOO server (Curtis, 1997) coupled with a client developed for each particular environment. To accommodate easy use on the Internet, the clients have been developed mainly in Java and VRML (Borchert et al., 2003), and are delivered to students using Java applets.

The IVEs described here are a combination of simulation and multi-user networked game. The student player is immersed in an authentic science learning context that is populated by other users and software agent avatars acting as tutors and guides. This defines a virtual world that synthesizes but does not replicate a large number of competing approaches. For example, the "SimCity" game is a single-user resource management game that provides a problem-solving context that is powerful but non-authentic. The "Oregon Trail" game provides a more authentic context, but is limited to resource management without an overriding science teaching agenda. The hugely popular "Everquest" simulation provides many of the attractions of socially situated experiences, but is not aimed towards teaching science content of any sort.

The WWWIC IVE systems are all constructed on the client-server model. A central server hosts a simulation of geological or biological processes. A client is launched as a Java applet through a Web browser. This approach keeps the client system safe from intrusion, because of the Java security model. The simulations are built on top of the publicly available LambdaMOO software. Server-to-client communication is accomplished through a system of low-bandwidth text-based directives. These directives control the client-side view of the simulation.

Developing IVEs for science education is both time intensive and expensive. It takes the concentrated effort of a team of content experts, designers, and computer specialists to develop a Geology Explorer or a Virtual Cell. The evidence, however, suggests that this effort and expense is worth the cost. Though the IVEs were originally

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