British Journal of Educational Technology *Vol 36 No 3 2005* 439–451

Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education

Michele D. Dickey

Michele Dickey is an assistant professor of Educational Technology in Educational Psychology at Miami University. Her current areas of research include interactive design and the use of emerging technologies for education. Address for correspondence: Dr Michele Dickey, Department of Educational Psychology, Miami University, Oxford, OH 45056, USA. Tel. 513 529 3741; email: dickeymd@muohio.edu

Abstract

Online three-dimensional (3D) virtual worlds are emerging technologies that offer unique learning opportunities for traditional and distributed education. One of the more popular 3D virtual worlds, Active Worlds, is currently being used as a medium for synchronous and asynchronous distance learning. This investigation presents two exploratory case studies of different, but exemplary educational activities using Active Worlds for formal and informal education. The focus of each case study is to investigate how Active Worlds is being used for distance learning and to determine the type of learning experiences afforded by this 3D virtual environment. Whilst more research is necessary to explore fully the potential of 3D virtual worlds for learning, this initial investigation illustrates how Active Worlds affords opportunities for experiential learning and situated learning within a collaboration learning environment.

Introduction

This past decade has yielded a proliferation of new and emerging technologies that have not only impacted the field of education, but have also challenged and expanded our ideas of what constitutes a learning environment. Amongst the new offerings in emerging technologies are online three-dimensional (3D) virtual worlds. Three-dimensional virtual worlds are a networked desktop virtual reality in which users move and interact in simulated 3D spaces. Typically, most rely upon text-based chat tools, although a few afford audio chat. Within the 3D environment, users are represented as individual avatars which both represent users in the 3D environment, and allow them to interact with other avatars and the environment. Several of the more popular 3D virtual world applications include Active Worlds, blaxxun interactive, OnLive! Traveler, and Adobe Atmosphere. Each application provides three important features: an interactive 3D

Published by Blackwell Publishing, 9600 Garsington Road, Oxford, OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

environment, avatars that serve as visual representations of users, and an interactive chat tool for users to communicate with one another.

Although 3D virtual worlds are still evolving, they afford the communicative and constructivist opportunities of text-based, chat-type applications such as Multiple User Domains Object Oriented (MOOs). Bruckman's (1997) investigation revealed that MOOs provide an environment that supports constructivist learning by allowing for the emergence of knowledge-building communities. These communities provide opportunities for peer role models, open classrooms and role reversal, and the presence of an appreciative audience amongst the community. Riner's (1996) research of educational MOOs further supports many of Bruckman's findings. According to Riner (1996), educational MOOs promote an interactive style of learning, opportunities for collaboration, and meaningful engagement across time and space, both within and across classrooms.

Whilst these findings are encouraging, 3D virtual worlds, unlike MOOs, provide visual representations of 3D space somewhat similar to that found in educational virtual reality (VR). Research in educational VR reveals that 3D interactive environments provide support for constructivist-based learning activities by allowing learners to interact directly with information from a first-person perspective (Bricken & Byrnes, 1993; Dede, 1995; Winn, 1997). Winn (1993) argues that information taught in schools is often presented as "third-person symbolic experiences," whereas innately, much of how we learn is through first-person nonsymbolic experiences. According to Winn (1993), VR can help bridge the gap between experiential learning and information representation.

Research from such diverse technologies as MOOs and VR indicate that there may be great potential for the use of 3D virtual worlds for education because they offer the multi-user synchronous communicative opportunities of MOOs combined with the visual 3D representations afforded by VR. The purpose of this research is to examine how one 3D virtual world application, Active Worlds, has been used synchronously and asynchronously for both formal and informal education. The goal of this research is to gain insight into what types of learning experiences 3D virtual worlds afford spatially distance learners.

The following questions were examined:

1. How is Active Worlds being used for distance learning?
2. What are the unique learning experiences afforded by this medium for spatially distant learners?

Theoretical framework

Much of the existing research about the educational use of such emerging technologies as text-based virtual worlds (eg, MOOs) and virtual reality is situated within a constructivist paradigm of learning (Bruckman, 1997; Bricken & Byrnes, 1993; Dede, 1995;

Riner, 1996; Winn, 1997; Winn & Jackson, 1999). The current wave within the field of instructional design is the cultivation of constructivist learning environments (Hannafin, Hall, Land & Hill, 1994; Hannafin, Land & Oliver, 1999; Jonassen, 1999; Scardamalia & Bereiter, 1996). Common characteristics of technology-enhanced constructivist learning environments include cognitive and collaborative tools, various types of scaffolding (conceptual, procedural, metacognitive coaching), and access to resources, models, and exemplars (Hannifin *et al*, 1999; Jonassen, 1999). A critical asset of constructivist learning environments is that students are provided with opportunities for interacting within and upon the environment (Johnson & Johnson, 1996). The theoretical assumption is that learners construct understandings by interacting with information, tools, and materials, as well as by collaborating with other learners.

Methodology

The research design for this investigation is a qualitative exploratory case study focusing on the unique learning opportunities afforded by this medium (Yin, 1994). Two case studies of different but exemplary educational activities are used to illustrate some of the potential 3D worlds afford as a medium for educational experiences. The first case study is an investigation of how Active Worlds has been used primarily asynchronously for formal education in an undergraduate business-computing course offered by the University of Colorado–Boulder College of Business. The second case study is an example of Active Worlds being used synchronously for an informal object-modelling course offered through Active Worlds University. Both case studies were chosen for this inquiry because they provide two diverse examples of how this medium may be used synchronously and asynchronously for formal and informal education.

Active Worlds overview

Active Worlds (AW) is a client-server application that allows developers to create unique 3D virtual worlds for users to visit and interact within. The AW browser interface is composed of four main windows which include a 3D environment; a chat tool; an integrated web browser; and a window for added navigational and communicational functions (see Figure 1). The windows are user-scalable and all but the 3D environment window may be closed. Users self-select a unique identity, which may not be used by any other user.

Within the 3D environment, avatars serve as the visual representation of users currently inhabiting a particular world. Users self-select an avatar from a library provided by an individual world. Avatars also serve as the camera or point-of-view for users in the 3D environment. Within the 3D environment, users may see all of the other users' avatars within a radius of 20 (AW) meters. Users may shift from first person in which they encounter the environment and other avatars from the perspective of their own avatar to third-person perspective in which they are able to view their avatar (back view) and others within the 3D environment. There are advantages and disadvantages to both perspectives. For example, it is helpful for users to shift to third-person perspective for activities such as building within the 3D environment. The third-person perspective is an isometric perspective which is slightly elevated and affords the user a

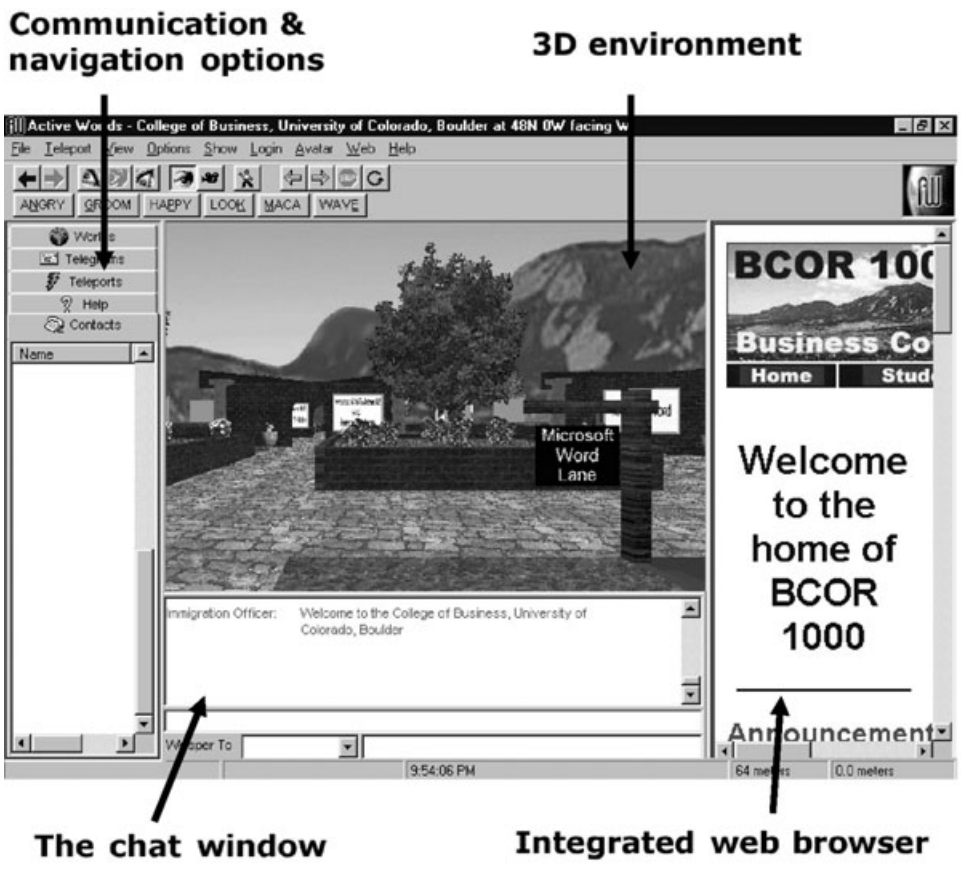

Figure 1: The Active Worlds browser

wider vantage view. However, this perspective also distances users from the impact of first-person discovery. In first-person perspectives users encounter the environment and other users as they move through the world, much like the physical realm. First-person perspective allows users to be embodied in the environment. Both perspectives have advantages and limitations, but users are free to shift between the two at any time.

Case study 1: Active Worlds as an asynchronous formal learning environment
University of Colorado–Boulder: Business Computing Skills 1000
The following is an account of participatory observations, and formal and informal interviews (in-person and online) with the faculty, design team, students, and staff of the virtual world setting of the Business Computing Skills 1000 (BCOR) course from May 1998 through May 2000. The virtual world setting was only one part of the Immersive Interactive Learning Environment (IILE), a grant-funded initiative directed

by Professor David E. Monarchi from 1996 to 2001. The IILE is a distance education course management system which incorporates various technology tools. The IILE system enables BCOR students to access course content using various tools including the use of AW to access the BCOR virtual world setting. This case study is limited to the virtual world setting only.

Background

Business Computing Skills 1000 is an entry-level, three credit-hour, required course for undergraduate business administration students at the University of Colorado–Boulder. The goal of the course is to foster business computing skills within a business-related context. Although the course is offered in a variety of formats (ie, traditional classroom setting, web-based environment, and 3D virtual world), this investigation is limited to the AW version of BCOR.

The BCOR curriculum covers a wide range of business-related concepts, such as computer security, information systems, and communication. These concepts are presented in tandem with such program applications as Microsoft Word, Excel, Access, and PowerPoint. Student assignments consist of weekly individual exercises designed to provide students with basic business-computing skills ranging from résumé writing to creating relational databases. In addition to these weekly assignments, students are required to participate in four collaborative group projects in which they apply and integrate their newly acquired skills into various projects that address several of the concepts covered in the curriculum.

Although the course design for BCOR is primarily asynchronous for the individual assignments, group assignments require student to meet and interact synchronously to collaborate. For the individual assignments, the BCOR virtual world provides the interface and context for the course. Students move from building to building to complete the assignments. They are able to submit assignments, review grades, and send and receive feedback online by way of the AW integrated web browser. Students collaborate on group projects by meeting in arranged meeting areas (patios) and by using the chat tool for communication.

BCOR: the setting/learning context

The setting for BCOR is a 3D world is made up of a spacious rectangular plaza surrounded by a backdrop image of the mountains that frame Boulder, Colorado. This setting serves as the interface for BCOR. Stone-lined roads extend on all four sides of the plaza leading to nearby buildings (see Figure 1). By moving east or west along one of the roads aptly named after each of the applications (eg, Microsoft Word Lane), students encounter a series of one-room buildings that each represent one of the various applications covered in the course. Each individual building represents a software application and an assignment that must be completed with that application. Within each building are signs that are web-linked resources for aiding students in learning that application. Clicking on a particular sign activates the integrated web browser to load a resource web site. To the rear of each building is a small patio that provides students with a place

Figure 2: A patio for collaborative assignments

to meet and collaborate on group projects (see Figure 2). Additionally, each patio contains signs that are hypertext links to web-based resources for the group projects. Whilst the 3D environment provides the interface, context, and environment for spatially distant learners to meet and interact, the web browser delivers content and resource information, as well as provides the means by which students submit work and receive feedback about assignments.

Findings

This 3D virtual world version of BCOR provides an example of how the structuring and presentation of information in a 3D environment may facilitate collaboration and community. The BCOR setting has been designed to provide a visual context for the course. It is a conceptual model for the organisation of the course materials as well as a context for many of the tools for learner interaction. This context builds on learners' real-world knowledge by providing a visual metaphor, or perhaps more aptly stated, a visual narrative of the course content. By using a 3D environment as a context for learning, the BCOR designers have created a *place* in which distributed learning is anchored in an environment that is both familiar and engaging. Visual cues such as buildings representing applications afford distance learners an intuitive interface for course structure as well as provide the necessary resources for learning. Roads and paths provide a

subtle guide to navigational paths through the course content. The use of buildings and patios along with the AW communication options afford users a visual context for collaborative work.

One of the goals of the course was to foster collaborative problem solving. Active Worlds proved an effective medium as spatially distance learners were observed to meet and collaborate on projects. Students were able to designate a meeting time and place for collaboration activities by using the chat tool. The open patios served as meeting places for group activities because the designers were able to build into the environment the links to exemplars, models, and resource information through the placement of billboards. When individual students clicked on a specific billboard, his/her integrated web browser loaded the linked material. This allowed learners the opportunity to view the same information at the same time whilst communicating using the chat tool. Because AW provides user-extensible world building, the BCOR design team was able to build a learning environment that fostered a sense of place, presence, and community for spatially distant learners.

The BCOR virtual setting was part of the IILE and only one of several ways in which BCOR student could access the course. Given the fact that students were encouraged to try all of the various tools, coupled with the level of anonymity afforded by AW's unique names, it was not possible to track individual students through the duration of the course; however, informal interviews with students revealed that most seemed to enjoy and value the use of the 3D setting. Most seemed impressed by the amount of work that went into creating the world. When asked about the advantage of this environment over traditional classroom or lab settings, most students predictably answered that the main advantage was "not having to go to class." However, upon deeper questioning, many students expressed that the environment made them feel like they were "at school" or "in school" or "actually there" embodied in the environment.

Interviews with Monarchi and members of the BCOR design team revealed that since the adoption of AW along with other tools, the course has become more popular and the attrition rate dropped significantly. Additionally, Monarchi argued that the use of AW supported a constructivist perspective by affording real-time communication and a visual environment and resources to support collaboration. The use of the 3D virtual world setting helped support the course objectives by providing a setting for students to apply their skills in a collaborative multidimensional environment.

One interesting aspect noted during observations and interactions with BCOR students is that the combination of the text chat tool, unique names, and avatars provides a sense of anonymity. At the beginning of the semester, prior to students' learning of each others' identities, students seemed to take great liberties in their interaction. Greetings such as "hey babe" were observed in more frequency than might be typically encountered (and tolerated) in a typical American undergraduate classroom. This may be attributed to the fact that the avatar selection for BCOR consisted primarily of representations of young, fit, shapely Caucasians. Although further research is needed, it is

believed that the lack of real-world kinaesthetic feedback, user anonymity, and the types of avatar representations likely impacted inhibitions and student interactions.

Case study 2: Active Worlds as a synchronous informal learning environment

Magine's 3D object modelling class

This case study focuses on Intro to RWX Modeling, a 3D object-modelling course for learning to create original AW objects. The following is an account of participatory observations, and formal and informal interviews from September 1998 through March 2000 of Active Worlds University (AWU) Intro to RWX Modeling class.

Background

Active Worlds University is a grass roots organisation of volunteers in the AW universe who provide training and education for both novice and advanced users. The overall curriculum of AWU is divided into the four programme areas of graphic arts, 3D object modelling, advanced AW building, and AW technology.

The AW browser uses RenderWare (RW) to display 3D environments by relying on RenderWare scripts (RWX) to define objects in the 3D setting. RenderWare is a commercially available "middleware" platform for supporting 3D virtual environments and 3D gaming environments. RenderWare scripts are text scripts that define the 3D object by listing vertices which in turn construct polygons. Additional information such as colour and texturing are also presented in text format. The curriculum for Intro to RWX Modeling consisted of an introduction to writing RWX, along with basic concepts and terms used in 3D modelling, such as the Cartesian coordinate system, polygons, vertices, shading, lighting, texturing, and colour.

The AW universe had a world dedicated to supporting educational initiatives. All classes took place in the Falling Waters Student Union within the AWU World (see Figure 3). The class instructor, Magine, is a programmer who designed the course curriculum and course materials.

Approximately 15 students attended class regularly and conducted themselves as they might in a more formal, traditional face-to-face class. Most class members revealed they were regular users of AW, with limited experience in 3D modelling.

Magine chose to offer her class as a synchronous in-world learning environment in which all of the students met at the same time and location within the AWU once a week for approximately 2 hours. Magine's teaching style was discussion oriented, with much interaction with and between students. Because the chat tool relies solely on text, interaction was dependent upon typing speed and skills as well as bandwidth. However, Magine's text always appeared boldfaced and was easily recognised and followed. During each class, typically, Magine presented a concept of 3D object modelling by way of the chat tool. To illustrate each concept, she provided examples of how the concept was actualised by presenting a sample 3D object in the 3D environment. She

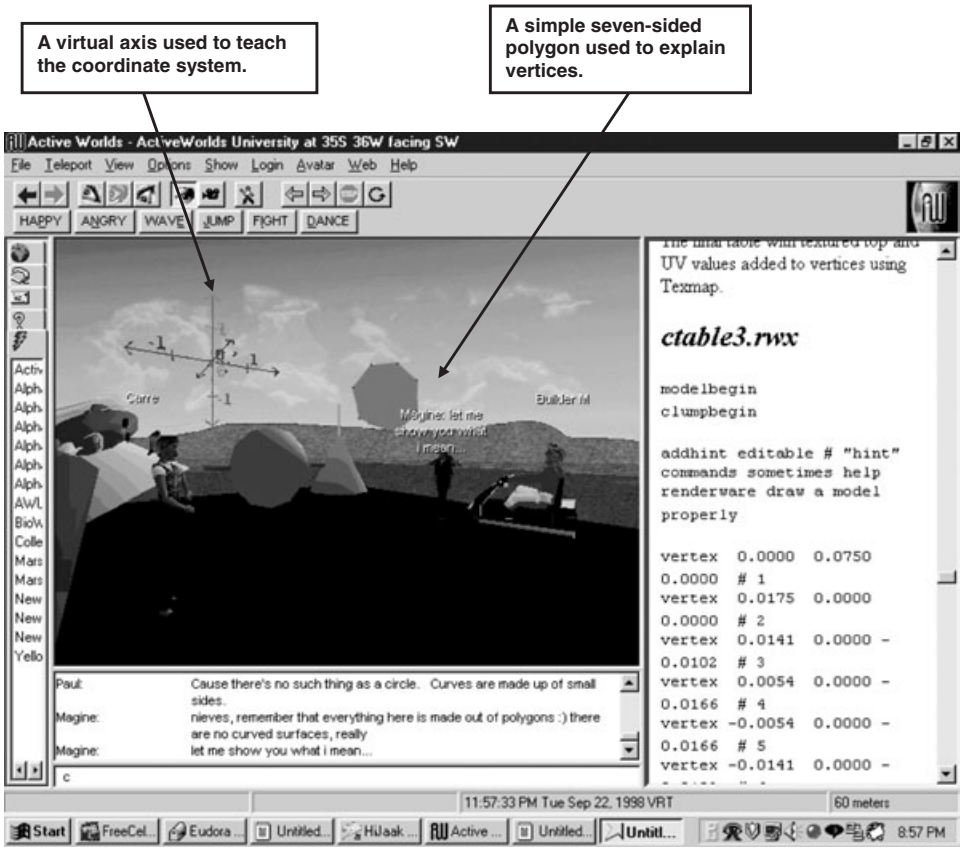

Figure 3: Magine's 3D object modelling class on the patio of the Falling Waters Student Union

provided further illustrations of how a technique or concept was constructed by supplying the underlying scripts of the object in the integrated web browser. This allowed learners the opportunity to follow the RWX script as well as see the resulting object in the 3D environment. For example, when Magine discussed the 3D coordinate system, she presented an axis in the 3D environment. Learners were able to move their avatars around the axis in order to understand how vertices on the axis define polygons.

Findings

Magine's Intro to RWX Modeling class illustrates some of the learning opportunities provided by using AW for distance education. Active Worlds allowed individuals interested in creating 3D objects the opportunity to learn in a collaborative and supportive environment. Magine's class also supported many characteristics of situated learning. Underlying situated learning is the belief that "knowledge is contextually situated and

is fundamentally influenced by the activity, context, and culture in which it is used" (McLellan, 1996, p. 6). Characteristics of situated learning include authentic context and activity (Brown, Collins & Duguid, 1996; Burke & McLellan, 1996), access to expert modelling (Brown *et al*, 1996; Cognition and Technology Group at Vanderbilt, 1996; Lave & Wenger, 1991), multiple roles and perspectives (Brown *et al*, 1996; Cognition and Technology Group at Vanderbilt, 1996), and scaffolding and mentoring (McLellan, 1996; Schlager, Poirer & Means, 1996).

Given the nature of this learning environment, coupled with the learning content, it would have been difficult to avoid providing authentic activities. Learners were immersed in both the content and culture of a 3D environment. Unlike 3D modelling classes offered in a more traditional setting, Magine's RWX object modelling class was situated in an environment made up of RWX objects, with learners literally represented as RWX objects. It might be argued that this learning environment afforded learners the opportunity, in a sense, to become embodied in the learning content and context. Instead of observing such actions as object rotation and translation from a third-person perspective, or as VR theorist William Winn (1993) deems, the *third-person non-symbolic* learners were able to construct an understanding from a first-person perspective by viewing these activities *as* the object.

Another characteristic of situated learning is the provision of learners having access to an expert or master. Magine, whilst being self-taught, is one of the more gifted object modellers in the AW universe. Most of the examples she provided for the class were her own creations. She made a point of explaining in detail how a particular example had been created as well as discussing some of the obstacles she had encountered.

During the duration of the course there was much evidence of learners adopting multiple roles and perspectives. Whilst this environment literally afforded learners the option of viewing most of the objects from multiple perspectives, there was evidence of learners also offering different perspectives for problem solving as well as taking on multiple roles by, at times, coaching other students and offering alternative explanations for complex concepts. This in turn allowed learners the opportunity to mentor each other as well as being mentored by Magine.

Discussion

Active Worlds has much educational potential worthy of further investigation. Communication features such as provisions for establishing a unique identity and the chat tool provides opportunities for collaborative and cooperative learning. During this decade, educators have focused on how collaboration and cooperation can enhance the learning process. Advocates of collaborative learning from a socio-constructivist perspective view knowledge as a social activity rather than as an individual cognitive process (Lave & Wenger, 1991; Vygotsky, 1978). Within the socio-constructivist paradigm, great value is placed on collaborative learning because it provides opportunities

for groups of learners to learn from each other by adopting new roles, offering multiple perspectives, becoming peer tutors, and taking on projects and tasks that would be difficult or impossible for a single learner (Johnson & Johnson, 1996). Active Worlds provides a means for spatially distant learners to converse and construct in a collaborative environment because of the types of design features it affords. Unique names provide both trust and accountability necessary for a collaborative learning environment, whilst at the same time allowing users to adopt a new personae or roles that might not be available to them in a traditional learning environment. Studies of the educational use of MOOs have noted the importance of learners being able to communicate and collaborate in the learning environment (Bruckman, 1997; Riner, 1996). Both BCOR and Magine's class provided environments that supported collaborative activities for learning.

Along with communication, AW provides potential educators and learners the availability to construct their 3D environment by building within an existing world or by creating a new world. These user-extensible options afford educators and learners the means to self-define the context of the learning environment. Links such as the billboards and signs found in the BCOR virtual environment provide opportunities for learners to gain new perspectives and understandings by interacting with materials, information, models, and tools. Whilst more research needs to be done of specific technologies like 3D virtual worlds, studies of VR environments reveal that immersive environments allow learners to interact with data or knowledge representations that are not possible to replicate in a traditional classroom setting (Byrne, 1996; Dede, Salzman & Loftin, 1996; Osberg, 1997). Whilst AW may lack all of the multisensory experiences available to learners in immersive VR environments, it provides opportunities for multiple means of representation and interaction.

The user-extensible options may also enhance learning by providing more opportunities for engagement. Within the constructivist paradigm, learning is not viewed as the transmission of ideas, facts, and theories, but rather learning is considered a process of constructing (Duffy & Cunningham, 1996). Activities that allow learners to create, problem-solve, make decisions, and reflect enhance engagement and learning. The user-extensible features that allow users to build and modify a world provide countless opportunities for constructivist activities dealing with both concrete and abstract representations of data and ideas.

In conclusion, both BCOR and Magine's class illustrate two ways in which one 3D virtual world is being used for both formal and informal learning. Both BCOR and Magine's RWX object modelling class demonstrate the innovative potential that one 3D virtual world affords for collaborative and distance learning. Whereas BCOR illustrates the powerful potential afforded by AW for facilitating collaboration, community, and experiential learning, Magine's class illustrates the ability for a learner to become situated and embodied in a computer-mediated learning environment. Like all emerging technologies for learning, much research is needed to fully understand the potential for distance and distributed learning.

References

Bruckman, A. (1997). *MOOSE crossing: construction, community, and learning in a networked virtual world for world for kids*. Retrieved 11, 02, 03, from http://www.cc.gatech.edu/~asb/thesis/index.html.

Bricken, M. & Byrnes, C. M. (1993). Summer students in virtual reality: a pilot study on educational applications of virtual reality technology. In A. Wexelblat (Ed.), *Virtual reality: applications and explorations* (pp. 199–217). Boston, MA: Academic.

Brown, J. S., Collins, C. & Duguid, P. (1996). Situated cognition and culture of learning. In H. McLellan (Ed.), *Situated learning perspectives* (pp. 19–44). NJ: Educational Technology Publications.

Burke, G. & McLellan, H. (1996). The algebra project: learning inspired by the Civil Rights Movement. In H. McLellan (Ed.), *Situated learning perspectives* (pp. 263–278). NJ: Educational Technology Publications.

Byrne, C. (1996). *Water on tap: the use of virtual reality as an educational tool*. Retrieved 10, 15, 03, from http://www.hitl.washington.edu/cgi-bin/db.cgi.

Cognition and Technology Group at Vanderbilt (1996). Anchored instruction and situated cognition revisited. In H. McLellan (Ed.), *Situated learning perspectives* (pp. 123–154). NJ: Educational Technology Publications.

Dede, C. (1995). The evolution of constructivist learning environments: immersion in distributed virtual worlds. *Educational Technology 35*, 46–52.

Dede, C., Salzman, M. & Loftin, R. (1996). The development of a virtual world for learning Newtonian mechanics. In P. Brusilovsky, P. Kommers & N. Strutz (Eds), *Multimedia, hypermedia, and virtual reality* (pp. 87–106). Berlin: Springer/Verlag.

Duffy, T. M. & Cunningham, D. J. (1996). Constructivism: implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 170–178). NY: Macmillan.

Hannafin, M. J., Hall, C., Land, S. & Hill, J. (1994). Learning in open environments: assumptions, methods, and implications. *Educational Technology 34*, 48–55.

Hannafin, M. J., Land, S. & Oliver, K. (1999). Open learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models*. Vol. *2* (pp. 115–140). Mahwah, NJ: Erlbaum.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models*. Vol. *2* (pp. 215–240). Mahwah, NJ: Erlbaum.

Johnson, D. W. & Johnson, R. T. (1996). Cooperation and the use of technology. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 1017–1044). NY: Macmillan.

Lave, J. & Wenger, E. (1991) *Situated learning: legitimate peripheral participation*. Cambridge, MA: Cambridge University Press).

McLellan, H. (1996). Situated learning: multiple perspectives. In H. McLellan (Ed.), *Situated learning perspectives* (pp. 5–17). NJ: Educational Technology Publications.

Osberg, K. M. (1997). *Constructivism in practice: the case for meaning-making in the virtual world*. HITL Report R-97-47. Retrieved 08, 20, 02, from http://www.hitl.washington.edu/publications/r-97-47/.

Riner, R. D. (1996). Virtual ethics← virtual reality. *Futures Research Quarterly 12*, 57–70.

Scardamalia, M. & Bereiter, C. (1996). Adapting and understanding: a case for cultures of schooling. In S. Vosniadou, E. Decorte, R. Glasa & H. Mandle (Eds), *International perspectives on the design of technology-supported learning environments* (pp. 149–163). Hillsdale, NJ: Erlbaum.

Schlager, M. S., Poirer, C. & Means, B. M. (1996). Mentors in the classroom: bringing the world outside in. In H. McLelland (Ed.), *Situated learning perspectives* (pp. 243–261). NJ: Educational Technology Publications.

Vygotsky, L. S. (1978) *Mind in society: the development of higher psychological processes*. MA: Harvard University Press).

Winn, W. D. (1993). *A conceptual basis for educational applications of virtual reality*. HITL Report R-93-9. Retrieved 06, 07, 00, from http://www.hitl.washington.edu/publications/r-93-9/.

Winn, W. (1997). *The impact of three-dimensional immersive virtual environments on modern pedagogy*. HITL Report R-97-15. Retrieved 12, 02, 01, from http://www.hitl.washington.edu/publications/r-97-15/.
Winn, W. & Jackson, R. (1999). Fourteen propositions about educational uses of virtual reality. *Educational Technology 39*, 5–14.
Yin, R. K. (1994) *Case study research: design and methods*. Thousand Oakes, CA: Sage).