Collaboration and Learning in Immersive Virtual Environments

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Abstract: We are investigating collaboration and learning in immersive virtual environments. Preliminary studies of 110 sixth and ninth grade students have been conducted where students worked in pairs while investigating the concept of global warming within a fully immersive, 3-D, virtual reality based model of Seattle called Global Change World (GCW). Field research being conducted during June of 1999 is expanding on these preliminary studies by seeking to identify differences in science concept learning between solitary users, paired-peer users, and agent-guided users interacting within the GCW virtual learning environment (VLE).We have observed that most students thoroughly enjoy their experiences with GCW. It is also apparent that peer collaboration plays a significant role in regards to the level of student engagement within the VLE. Therefore, we believe that the potential for GCW to facilitate valuable collaborative learning experiences in conjunction with more traditional classroom activities is great. Our continuing research is intended to focus more closely on the impact of both peer and expert-novice collaboration on the preconceived or "naive" scientific concepts held by students. The paper that follows describes our research to date, and will be amended to include the methods and results of our research-in-progress.

Keywords: conceptual change, multi-user virtual environments, virtual reality

Introduction

The application of virtual reality (VR) to the educational process is becoming more commonplace, with large numbers of students of all ages experiencing virtual environments (VEs) in educational settings. For example, Youngblut (1998) identifies over forty examples of VR applications that are specifically designed to support learning. These learning experiences can come in many forms, from virtual worlds created via VRML to fully immersive VEs that utilize stereoscopic headmounted display systems. Moreover, with ever-increasing computational processing power, the rapid growth of the World Wide Web, and the ongoing construction of a digital communications infrastructure, the creation of distributed fully immersive, multi-participant VEs running on the Internet are on the technological horizon. Given the growing interest in distance learning and distributed education among educators, it is fair to assume that many fully immersive, multi-participant, educational VEs will come on line as the technology becomes less expensive and more readily available.

Most educational applications of VR are designed to make use of its unique features. These features provide opportunities for students to gain a greater understanding of abstract concepts through the creation of visual metaphors or representations and the ability to scale and manipulate these representations. Working with these representations allows students to investigate relationships between objects in VEs which are unbounded by distance, time, or safety concerns. Designers of educational VEs believe that students retain, master and generalize new knowledge better when given the opportunity to become actively involved in constructing that knowledge through a coherent, firsthand interaction with knowledge domain representations (Winn, 1993).

As it becomes possible to place more than one student within a VE, questions arise regarding the potential impact of collaboration on learning. The purpose of this paper is to report the progress of a proof-of-concept project which is being conducted by members of the University of Washingtonís College of Education and the Learning Center at the Human Interface Technology Laboratory (HITL) at the University of Washington. Funded by a grant from the UW Royalty Research Fund, this project seeks to investigate the nature of peer collaboration within VEs. We describe an investigation that looked at how easily school children adapted to working together towards the ultimate goal of developing and testing hypotheses regarding environmental factors that affect climate change in a VE designed for use in science education.

Background

Arriving at an understanding of exactly how to use immersive VR to support the teaching and learning of abstract concepts continues to be a challenging and elusive goal for researchers of virtual learning environments (VLEs). The potential for VR to benefit education is widely recognized and a number of studies have been conducted that have demonstrated a capability to teach content using VR under certain prescribed conditions (e.g. Byrne, 1996; Dede, 1995; McLellan, 1996; Osberg, 1997; Winn, 1997; Youngblut, 1998). A significant challenge, however, remains in fusing of the affordances of VLEs and educational methods of exploiting them into a demonstrable theory of learning for VR.

Zeltzer (1992) refers to the three attributes of autonomy, presence, and interaction in describing the affordances VR provides. Autonomy refers to the notion that a virtual environment (VE) is to some extent capable of performing its own actions, independent of user intervention. An autonomous VE follows its own path to goals and may or may not change course in response to user actions. Presence is simply the experience the user has of being in a real place when immersed within a VE. Zeltzer claims that for presence to be high, the user must be allowed to interact with the VE both naturally and intuitively; when presence is high the computer interface disappears. Finally, interaction involves the ability of the user to perform actions in the VE according to a logical rationale. Even though the user may have to learn how to function appropriately within the environment, the laws that govern the VE should become apparent over time, allowing for a meaningful interactive experience.

Most educational applications for VR are designed to make use of these and other unique features and affordances. Other affordances include: 1. Allowing students to gain a greater understanding of abstract concepts through the creation of visual metaphors, 2. Allowing students to directly manipulate and scale virtual objects or environments for clearer understandings, and 3. Allowing students to visit places and interact with events that distance, time, or safety concerns would normally prohibit (Winn, 1993, Youngblut, 1998). Designers of VLEs tend to believe that students retain, master and generalize new knowledge better when given the opportunity to become actively involved in constructing that knowledge through a coherent, firsthand interaction with knowledge domain representations.

Much of the appeal for applying VR in education is derived from the observations of educational theorists like Bruner (1986) and Piaget (1929) who have long stressed the value of actualizing learning through making it more real for students. VR technology allows for the creation of a VLEs where students can learn by interacting with virtual objects similar to how they would interact with real objects. Through immersion in a VE, students become a part of the phenomena that surround them. Learning is facilitated through the construction of concepts built from the intuitions that arise out of their direct experience of the environment. More recently, research (Clancey, 1993; Bricken, 1990) has supported the notion that VLEs, by their very nature, increase the human capacity for certain types of learning by allowing users to cross the boundary between third and first person experience, negating the need for a highly abstract symbol system. In traditional education, learning the symbol system of a particular knowledge domain is often a prerequisite to learning its content, as in the case of mathematics or music (Winn, 1993). The problem with this type of learning is that mastery of the symbol system can often be mistaken for mastery of the content, and teaching may end well before students make the link between the two.

First person, or direct, interaction within a VE allows students to construct knowledge out of their own experience without relying on symbol systems. This concept of knowledge construction among learners is more generally referred to as constructivism (Duffy & Jonassen, 1992). Self-constructed knowledge is highly individualized and may represent an improvement over similar knowledge learned by other methods because the learners shape the learning experience themselves. In other words, instead of relying on third-person instructor or text-based accounts of how things occur in the world, students immersed within VLEs can directly experience and interact with the concepts, principles, rules, and procedures found in the domain. VLEs designed from the constructivist approach are seen by some as having great potential for providing powerful learning experiences (Bricken, 1990).

Constructivism has entertained a long history in education and philosophy and is representative of a wide diversity of views that may be summed up in the following points: 1. Learning is an active process of constructing rather than acquiring knowledge, and 2. Instruction is a process of supporting that construction rather than communicating knowledge (Duffy & Cunningham, 1996). While constructivism is seen to imply that there is a tangible world, it argues that it is individuals who impose meaning on that world. Consequently, there can be many meanings or perspectives for any event or concept and the goal of education can no longer be one of instilling an absolute, correct meaning (Duffy & Jonassen, 1992). More importantly, constructivism brings with it the underlying assumption of a learner-centered approach to instruction. Constructivist arguments are often used to defend the design and implementation of VLEs.

Traditionally, most VLEs have placed a single student within the VE. However, as the technology becomes available educators are becoming interested in investigating the potential for collaborative learning in VEs. There has been considerable research on the value of collaborative learning. OíMalley (1995) found that much of the research on collaborative learning has evolved from the works of Piaget (1985) and Vygotsky (1978). Crook (1994), for example, views peer collaboration as having three basic cognitive benefits; articulation, conflict, and co-construction. According to Crook, peer collaboration forces students to make their ideas explicit and public. To do so, they need to learn to clearly articulate their opinions, predictions, and interpretations. Conflict may arise when students disagree in regards to their interpretations. To resolve the conflict engendered by collaboration, they must justify and defend their positions and are thus forced into reflection. Piaget (1985) offered a similar view, noting that socio-cognitive conflict often arises when students holding inadequate or differing views work collaboratively. As these differing views are sorted out, students are forced to reflect upon their own conceptions. Crookís concept of co-construction is based upon Vygotskyís (1978) belief that learning is the sharing of meaning in a social context. Students collaboratively co-construct shared knowledge and understanding by building upon each otherís ideas. Given the ability of VLEs to support multi-participant activities, it is easy to see why educators are very interested in examining the potential for using them to support collaborative learning.

Global Change World

Global Change World (GCW) is a VLE that was designed and programmed by the Learning Center of the Human Interface Technology Lab (HITL) on the University of Washington campus. The GCW environment is created by two networked Hewlett-Packard 9000 workstations running DVISE VR software. Hardware manufactured by Division provides the physical user-interface and consists of an audio/visual rendering system connected to a headmounted display helmet (HMD), a navigation and control wand, and a position tracking system. GCW is capable of supporting peer collaboration by allowing more than one student to be immersed and interactive within the same VE at the same time.

In GCW, student pairs enter a virtual model of Seattle in the current year. They are able to navigate their way around the world using the wand while viewing the world through the stereoscopic HMD. Within the world, the virtual representation of each of the participants appears to the other as a cartoonish pair of large eyes, spiral ears, a triangular-shaped mouth, and a singular cyber hand with which they can manipulate objects. In addition, students are able to speak to and hear each other by means of an intercom system that is built into the HMD. In order to perform tasks within GCW, students access a virtual tool kit that allows them to measure air temperature, amount of greenhouse gasses in parts per million, and yearly rainfall. They are able to adjust such variables as the amount of green plant biomass as symbolized by trees, the number of factories, and the number of automobiles present in the world. After making measurements and adjustments, they can then use a "time portal" to go to a selected year in the future and repeat their measurements in order to determine the impact of their actions on the climate of the future.

In preliminary studies, GCW has been taken to College Place Elementary School in Edmonds, Washington, and Redmond Junior High School in Redmond, Washington where a total of 110 students have participated in collaborative VLE activities. Through these visits we hoped to gather information concerning the educational effectiveness of employing a multi-participant VE as a science education tool. Our subjects were eighteen 11 and 12 year-old boys and girls (9 female, 9 male) from a single sixth-grade class and ninety-two 14 and 15 year-old boys and girls (47 female, 45 male) from three ninth-grade class sections. Differences in navigation and general task performance abilities between the older students and the younger students did not appear to be substantial.

Our first task was simply to familiarize the students with the interface, scientific measuring tasks, and basic nature of GCW. The goal of this first phase of the GCW peer collaboration investigation was to observe and record the student interactions with each other in both world navigation and in performing specific tasks. As noted earlier, the HMDs were fitted with microphones so that the students could speak to each other from within the world. This allowed the students to communicate with each other in their normal voice and appeared to improve communication, facilitate collaboration and enhance feelings of presence. Each student pair spent an average of 20 minutes in GCW.

Results

Upon exiting GCW, students were given a nine-question survey that employed a Likert-type scale. The questionnaire asked them to rate the quality of their experiences within the VE. The results of the survey indicated that the students found the experience to be highly enjoyable and most students said they would like to repeat the experience. About 5% of the students reported malaise (dizziness or disorientation). A few students reported problems with using the wand and seeing clearly in the HMD. Ratings of presence were high for most respondents.

Clearly, the overwhelming majority of students thoroughly enjoyed their experience with GCW and most of the students felt highly immersed within the VE. It was apparent that peer collaboration played a significant role in regards to the level of student engagement within the VE. The ability of the students to speak clearly to each other while in the VE seemed to greatly facilitate peer collaboration. Many pairs of students were highly communicative. As they navigated through the world or performed the requested tasks, they were engaged in near constant conversation regarding where to go, what to do next, and how to do things.

Observation revealed substantial peer collaboration among almost all pairings of students, though some pairs needed initial prompting and encouragement to begin conversing with their partner. Expert/expert pairs of females, who were comfortable with the interface, were the most vocally communicative. Novice/expert and novice/novice pairings of all gender combinations were somewhat less communicative. Expert/expert male pairings appeared to involve more action, such as racing, but still incorporated a significant amount of conversation, as well as the inclusion of vocal "sound-effects" that were related to actions being made, particularly among the younger students.

Male/female expert/expert pairings, as well as male/female expert/novice parings, resulted in what appeared to be a more self-reflective, thinking out loud style of conversation with the experts doing far more talking. These pairs would play hide-and-seek, in the case of experts, or simply try to keep track of each other by talking about what they were seeing. Most groups developed strategies for finding each other by identifying prominent landmarks and agreeing to meet at them. Some individuals picked up and carried large brightly colored objects, such as cars or boats, and waved them around or carried them along with them so the other at a distance could see them.

Though students can fly through the world with their hand controller, many of them were physically active as well. Many students were observed to be pointing at virtual objects with their free hand in the real world while talking to their companion in the virtual world. Several students were quite surprised that they had walked almost halfway across the room when we removed the HMD; they had assumed that they stood fairly still while they were flying around the VE. The students who were the most at ease with the interface were the most animated in their physical movements while immersed within GCW.

A number of students found GCW to be easy to use and made full use of the tools provided. These subjects quickly mastered navigational skills and the use of the environment measuring tools that allowed them to view the VEís current temperature, the amount of greenhouse gases present, and the amount of annual rainfall. While in the world, they were instructed on the use of the wheels controlling the quantity of the VE variables of cars, factories, and biomass. These students flew through the time portal, time and time again, in efforts to determine what the impacts of their changes would be and test theories regarding what changing the variables would do to the environment over time. These students typically rated the experience highly and reported a strong sensation of immersion.

Other students, however, had more difficulty mastering the use of the environmental tool kit and in trying to come up with theories for future environmental outcomes based upon changes made to the variables. Some dyads never got to the point of being comfortable enough with the interface to successfully investigate the environmental research elements of GCW. Those who did often disagreed on the expected outcomes. Time, as well as the scope of this preliminary study, did not allow us to perform a further investigation into the existence or nature of hypothesis generation and testing within GCW. We do know that the students were highly motivated, very willing to work in pairs, interested in exploring virtual space, and capable of performing investigative tasks within GCW. Further research that focuses more closely on the impact of peer collaboration on preconceived or "naive" scientific concepts and the possible conceptual change inspired by collaboration within GCW is planned and data collection will be underway throughout 1999.

Concluding Remarks

While the potential for VR to facilitate collaborative learning experiences appears to be great, much more research is needed before effective collaborative learning strategies can be developed. It is anticipated that these strategies will vary, depending on the kind of educational experience desired and the learning environment employed. However, for this potential to be realized, designers of hardware, software, and instruction must make sure that it is easy for multiple participants to collaboratively navigate and perform within VEs. This requires improvements of today's input devices including improvements in spatialized audio systems, less cumbersome HMDs, simpler wands, and the eventual introduction of haptic (force feedback) devices. The need for these technical advances is essential, considering that the networking of multi-participant, collaborative virtual environments appears to represent a significant trend for future applications of VR both within and outside of the educational domain.

Bibliography

Bricken, W. (1990). *Learning in virtual reality* (HITL Memo No. M-90-5). Seattle, WA: Human Interface Technology Laboratory. [Available as online HTML document: http://www.hitl.washington.edu/publications/m-90-5].

Bruner, J. (1986). *Actual Minds, Possible Worlds*. Cambridge, MA: Harvard University Press.

Byrne, C. M. (1996). *Water on Tap: The Use of Virtual Reality as an Educational Tool.* Unpublished Ph.D. Dissertation, University of Washington, Seattle.

Clancey, W.J. (1993). Situated action: A neuropsychological interpretation: Response to Vera and Simon. *Cognitive Science*, 17, 87-116.

Crook, C. (1994). *Computers and the collaborative experiences of learning*. London: Routledge.

Dede, C. (1995). The Evolution of Constructivist Learning Environments: Immersion in Distributed, Virtual Worlds. *Educational Technology, 35*(5), 46-52.

Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the Design and Delivery of Instruction. In D. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* . New York, NY: Simon & Shuster Macmillan.

Duffy, T. M., & Jonassen, D. H. (1992). Constructivism: New Implications for Instructional Technology. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction : A conversation* . Mahwah, NJ: Lawrence Erlbaum Associates.

McLellan, H. (1996). Virtual Realities. In D. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* . New York, NY: Simon & Shuster Macmillan.

OíMalley, C. (Ed.)(1995). *Computer supported collaborative learning*. New York: Springer-Verlag.

Osberg, K. M. (1997). *Constructivism in Practice: The Case for Meaning-making in the Virtual World.* Unpublished Ph.D. Dissertation, University of Washington, Seattle.

Piaget, J. (1929). *The Child's Conception of the World*. New York, NY: Harcourt & Brace.

Piaget, J. (1985). *The equilibration of cognitive structure*. Chicago: Chicago University Press.

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

Winn, W. (1993). *A conceptual basis for educational applications of virtual reality*. (HITL Technical Report No. TR-93-9). Seattle, WA: Human Interface Technology Laboratory. [Available as online HTML document: http://www.hitl.washington.edu/publications/r-93-9].

Winn, W. (1997). *The Impact of Three-Dimensional Immersive Virtual Environments on Modern Pedagogy*. HIT Lab Technical Report R-97-15. Seattle: Human Interface Technology Laboratory.

Youngblut, C. (1998). *Educational uses of virtual reality technology*. Alexandria, VA: Institute for Defense Analyses (IDA Document D-2128).

Zeltzer, D. (1992). Autonomy, interaction, and presence. *Presence*, 1, 127-132.

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