Situational Learning in Real and Virtual Space: Lessons Learned and Future Directions

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Figure 1: The far left image is of children on a hike. The second left image is of a Trillium. The first image on the right is a screen capture from a research project "Virtual Beechwood, Simulated Ecological Environments for Education" [Harrington 2005] and the far right image is a wire frame example from the research project.

Abstract

This work started with the informal observation of my daughter as she actively inquired about her world around her. Her seemingly innocent questions have profound implications for real time science education. How could these common daily experiences of information seeking behavior be supported or augmented, and transferred to a virtual or augmented reality application for education and knowledge acquisition? How to make it effective? What research has been done? This paper highlights key educational research and reviews important empirical findings from science education implemented in virtual reality and other computer graphics technologies. Based on recent literature and user interface design experience a list of design heuristics and recommendations are offered as guidelines to virtual reality educators and software developers. Lastly, there is a summary of future research opportunities and challenges.

CR Categories: H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces; I.3.7 [Three-Dimensional Graphics and Realism]: Virtual reality; K.3.0 [Computers and Education]

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1 Real World Situated Learning

Elementary school lessons are largely taught to children in the classroom. The curriculum may include separate units on English, math, science, history, social studies, foreign language and others. Most material is presented in conventional ways; with books, lectures, and in class or labs activities. On certain occasions, the teacher will incorporate stories, videos or web sites.

At other times songs will be sung, art works will be created or models such as a terrarium or dioramas made. Additionally, the school may have access to artifacts from a traveling museum collection that can be integrated. Scheduled field trips to local places of interest, such as trips to a science center, museum or to a local nature reserve with an expert in the subject area provide meaningful experiences and ways to interact with and explore information in a broader context. It represents the best in Situated Learning Theory [Lave and Wenger 1990; McLellan 1995]. Furthermore, these experiences even with a parent or friend offer meaningful learning opportunities, especially for the rich "*Cognitive Ecology*" available in many places and the opportunity to nurture the child's development of "*Islands of Expertise*" [Crowley and Jacobs 2002].

This broader context is spatial, temporal and multi-faceted. On site the children can see, hear, feel, smell and even taste items under investigation, essentially a multi-signal, multi-modal, real-time, situational learning environment. The theory of Multiple Intelligences [Gardner 1993] suggests the power this type of multi-sensory experience has as it provides many kinds of signals varying in importance for each child. Integrating data, information and knowledge from the experience can leave a lasting and meaningful impression, resulting in deep conceptual change for the child.

2 Virtual World Situated Learning

Given that many of these educational techniques are viewed as beneficial and constructive for learning in the real world, the issue becomes one of replication and distribution in the current technology paradigm. Hence, in the past we saw the development of computer based training, intelligent tutors, knowledge acquisition systems and simulations and virtual world tools and applications. Investigated techniques proven to be beneficial are Problem-Based Learning and Cognitive Apprenticeship approaches [Bransford et al. 1990]. These applications facilitated training by engaging many cognitive functions, situational tasks, emotional enjoyment, planning and envisioning as well as decision making. The advantage of virtual reality over the other types of training systems is the Gibsonian ideal and argument for Ecological validity [Gibson 1979] .

The unique functionality of virtual reality, as a technology that can be used to construct *Spatial Cognitive Ecologies*, of visual or multi-signal interpretations of past and future realities, or scaled realities from microscopic to galactic dimensions, or user interfaces that also allow the child to adopt multiple views of reference or roles, is unique to this technology and is often cited as some of the benefits of this technology.

Additionally, the empirical results from non-educational virtual reality research offer transferable practices to this domain. Some of the results are from simulations for task training [Rickel and Johnson 1999] , others are design activities [Rosenbloom 2004], some focus on higher level decision making [Flaxman 2004], and others are the visualization of large data sets used for exploration, pattern discovery and investigation [PRISM 2005]. Furthermore, data visualizations and user interface augmentation of the virtual world can facilitate operation and ease of use [Bowman et al. 2003].

3 Early Environments for Education

The early virtual environments and simulations were expensive, and often incorporated high end computer graphics, many times with immersive systems that required highly skilled development teams and resulted in long development cycles. However, the barriers of time and money did not deter the early efforts; it did however, limit the number of projects. Thus, the number of empirical studies for education and virtual reality was relatively low [Youngblut 1998].

Since the early 1990's, virtual reality has been investigated for use in education with children [Dede 1995; Johnson 1999; Salzman et al. 1996; Wickens 1992; Winn 1993]. The most significant research to date has been produced at top research universities: MIT, University of Illinois at Chicago's Electronic Visualization Lab (EVL), University of Washington's Human Interaction Technology Lab (HITLab), Harvard University, University of Nottingham and Georgia Institute of Technology, just to name a few.

Other efforts were sound educationally, but lacked the high end computer graphics sophistication available to the military or the entertainment segments, yet offer many design approaches that can be transferred to new virtual reality applications. Applications anchoring science instruction in multi-media learning environments has proven to be effective [Goldman et al. 1996]. Some projects have focused on using multi-media user interfaces with intelligent tutors. Some of the most well known projects are the Wetlands Ecology, Hi-Ce Model-It, *What is the Water Like in our River?*, from the University of Michigan's Center for Highly Interactive Computing in Education and the notable videodisc program, *Jasper Woodbury Problem Solving Series* by the Cognition and Technology Group at Vanderbilt.

The Jasper Woodbury project used the highly effective teaching technique of problem based instruction strategy. Such projects in multimedia offer design approaches that represent conceivable future directions in design approaches transferred to virtual reality educational research.

4 Augmenting the Real with the Virtual

Research has shown that learning does occur in virtual environments. Specifically, knowledge gain has been reported in the experimental results of the Maxwell World project as close to 20% [Dede et al. 1995, 1996, 1997 & 1999; Salzman et al. 1996; Salzman et al. 1999] and in Virtual Environments in Biology Teaching as close to 50% [Markopoulos 2003] and in the MUVEs work as close to 35% [Dede et al. 2003, 2005].

Additionally, the research has shown, and in an overwhelming majority of the qualitative reports of all projects reviewed, that enjoyment, engagement and increased attention are reported attributes of virtual environments for education. The strongest of which was reported by Dede [2003, 2005] as data was quantitatively gathered on the proxy variables of attendance, absenteeism and the use of profane language of classroom virtual environments. Furthermore, Dede [2005] reported that absentee rates decreased by 35% and the use of profane language dropped by 81%. For classroom-based systems, these factors are valuable quantitative proxy variables that can be indicators of "presence, engagement, and immersion."

There are many open questions related to the factors that contribute to or distract from the act of learning in a virtual reality environment. Some may be social issues, hardware issues, network issues and of course, the content and curriculum quality issues as well. Additionally, the research design, methods, and testing environments will have an impact on the type of data gathered and thus the evaluation and comparisons possible. The following highlights major themes observed, and lists the heuristics found to correlate with significant results.

5 Lessons Learned

In addition to the general themes discussed in the previous section one can also identify user interface design heuristics and empirical research guidelines for assessing the impact of virtual reality applications on education. These guidelines are presented in an attempt to help create a more consistent approach to designing, evaluating and measuring such systems. These heuristics can be used when comparing virtual environments for educational use and can be used to guide future designs.

Furthermore, it represents a rich area for future collaborative research opportunity. As a community, we should create an extensible on line ontology editor and an open source code repository for communication and leveraging of software components as is advocated in *collect-relate-create-donate* [Shneiderman 2003].

6 Heuristics for Designing and Testing Simulated Ecological Environments for Education (SEEE)

1 Educational Research Design

a. Use a control group.

b. Use pretest, posttest and log activity.

c. Know what you are measuring (causal, independent and dependent variables) and how to measure it before the experiment.

d. Define a rubric or ontology of the information both declarative and procedural.

e. Can the activity be compared to a group that learns the concept in the traditional way? If so, design the experiment to assess the gain. Is it better than the current method?

f. Separate content (educational material) from form and function (virtual environment and user interface). Decompose and measure the impacts of each.

g. Children paired with peers, a parent, a teacher or in collaborative groups of trustworthy friends will on average reduced inhibition of exploration tasks.

2 Simulation and Virtual Reality

h. If interacting with Artificial Life, make the models "look and behave" realistically.

i. Designer selected frame of reference views will influence what the user attends; so choose carefully and intentionally.

j. Scale, either very small or very large can be used to advantage in this medium.

k. Routes, landmarks and textured regions facilitate egocentric way finding, but when the level of detail is too low, the children will fail to navigate in a meaningful way, thus provide exocentric views.

l. Provide context of all types.

3 User Interface

m. If possible, make it true 3D, stereoscopic.

n. Use natural interfaces, such as voice recognition and gesture.

o. Use a large CAVE /DOME with controls that facilitate unencumbered interaction, or a standard desktop with controls that the children know how to use.

p. Interaction must be real time with out lags.

q. If using sound, it should be spatial and the sound should be perceived as emitted from the direction of the source.

r. Use scientific visualization to show data that can not be seen.

s. Carefully use, multi-channel redundancy gains, but not to the point of creating noise.

t. If a user becomes the avatar or object, allow for the adoption of multiple roles or frames of reference.

u. If alone, have a guide or avatar available for help.

v. Cause and effect relationships must be very clear, for learning of correlations to occur in both the user interface and the content material.

7 Conclusion and Future Directions

The result of this research project is hoped to provide ideas, insights and a matrix for future research. Future research will focus on building, testing, evaluating and creating models of these kinds of systems. The user interface in terms of the hardware, the software and the underlying models as well as the intelligent tutors are all factors to consider. Future work will be on modifications to the user interface.

Certainly, if games are used, it will be paramount to remove all of the first person shooter components; perhaps in the future the venders will facilitate this effort by offering educational versions. The future may not be in "games to teach", but in high end simulations of real world learning activities produced by expert teachers with very low cost, but high end computer graphics technology to meet the educational and learning needs of children.

Of high importance will be the users' task, engaging the child in acts of situational learning in real and or virtual space. It is an opportunity for educators and software developers alike, not only could such tools have enormous social, humanitarian and ecological impacts, but also economic, as the educational market may prove to be larger than the game market.

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