Immersive Interactive Virtual Reality and Informal Education

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Abstract. Research in conceptual learning and virtual reality is a relatively young field, but growing rapidly.
The increasing development of virtual reality (VR) technologies has matured enough as to expand research from the military and scientific visualization realm into more multidisciplinary areas, such as education, art, and psychology. Consequently, virtual reality interfaces, interaction techniques, and devices have improved greatly in order to provide more natural and obvious modes of interaction and motivational elements. Nevertheless, the prohibitive costs and inaccessibility of VR technologies, coupled with issues of usability, educator training, operation, and maintenance, present important drawbacks for the educational use of VR making it difficult to incorporate in dwindling school budgets. In spite of these concerns and objections regarding the appropriateness and educational efficacy of virtual reality, there remain compelling reasons for believing that VR learning environments for children warrant serious investigation and can provide strong tools for learning. Institutions of informal education, such as museums, research, and cultural centers are in a better position to make use of such advanced systems and investigate their educational potential while effectively shaping how they deliver public education. This paper describes the interactive learning environments developed for learners of all ages in such an institution of informal education, and discusses the issues involved in using state-of-the-art interactive virtual environments for childhood learning.

1.   BACKGROUND

The development of new interactive technologies inevitably has an impact on all aspects of teaching and learning. This is more evident in the case of novel interactive technologies that fascinate the broad public, as is Virtual Reality (VR). Research in virtual reality and education is a relatively young field but in recent years it has shown considerable growth.

There exist many compelling reasons for believing that VR learning environments for children warrant serious investigation. There is general agreement that VR can have strong motivational impact (Bricken, 1991); ongoing efforts at characterizing phenomena such as immersion and presence are beginning to clarify these effects (Winn, 1993; Slater and Wilbur, 1997). VR affords opportunities to experience environments which, for reasons of time, distance, scale, and safety, would not otherwise be available to many young children, especially those with disabilities (Cromby et al., 1995). Early exposure to virtual environments may both leverage the well-known efficiency and capacity of children's learning and provide advance organizers for later learning experiences (Dede, 1998). Usability issues which plague adult VR users may prove less problematic among children, who both easily adapt to graphic and conceptual abstraction (in cartoons and comics) and who often have extensive experience in navigation 3-D spaces and discovering and exercising interface affordances (Provenzo, 1991).

Several educational virtual reality projects have been created that focus on the advantages mentioned above. A recent report that comprehensively surveys work over the past few years in the area, cites approximately 50 VR-based learning applications which include desktop but exclude text-based virtual environments (Youngblut, 1998). So far, research has shown that most of the projects developed involve the elements of exploration (as achieved by the extended range of sensory stimuli provided), creativity (through environments based on the theories of constructionist forms of learning), and collaboration between both remote and collocated learners (through collective decision making, peer teaching, etc.) Although research in the field remains exploratory in nature, the fairly limited evaluation studies performed have focused on the aspects of motivation, control, construction of mental models, collaboration, usability, orientation, and multisensory activity.

2.   INFORMAL EDUCATION

Institutions of informal education such as museums are now beginning to utilize more recent information technology for internal and external organizational purposes while an increasing number of interactive exhibits are incorporated into galleries in order to enhance the visitor experience. Museums realize that they are one among many components in a panoply of cultural amenities and that computer technology can help them quantitatively and qualitatively expand, deepen, and enhance the museum experience for their visitors. A growing number of museum educators regard new media as tools that can offer unparalleled opportunities for learning. Through educational web sites and CD-ROMs, museums have enhanced their role as providers of informal education. Educators respond to such efforts favorably as these provide alternatives to restricted curriculum material and allow for more exploration and ownership of the learning process. Finally, museum visitors, especially non-frequent and novice audiences, appreciate and benefit greatly from additional forms of information that make the museum a more accessible and attractive place for them to spend time in (Thomas and Mintz, 1998).

Although very few, there are ambitious and significant efforts taking place in museums worldwide that have used high-end technology to complement their exhibitions. Science museums, hands-on children's museums, large "edutainment" venues, and recreation parks have traditionally been the ones to embrace new media first and employ fascinating and sophisticated interactive virtual reality installations that go beyond the point-and-click of common multimedia and information stations. Current museum theory and practice suggests that technology, as incorporated in today's exhibitions, should generally evolve through two successful formats: inquiry-based educational activities and interactive hands-on exhibits. The explosive development of information technology and the increasing confidence on the part of the museums to incorporate it in their setting has encouraged many institutions to adopt sophisticated technological means, innovative environments, and equipment. Hence, we see more and more often museums considering the use of interactive installations, simulation environments, interactive film, large format theaters or equivalent smaller scale exhibits, and virtual reality.

Of particular interest to museums in the use of virtual reality displays and computer-generated interactive experiences is the fact that they can allow visitors to travel through space and time without stepping out of the museum building (Roussou and Efraimoglou, 1999). The potential to transcend the physical location of the built environment and the growing sense of the educative function of the museum juxtaposed with the commercial pressure has lead museums

to consider virtual reality as a necessary component in the arsenal of tools to educate, entertain, and dazzle. Although virtual reality suffers immensely from media hyperbole and thus has not lived up to its promises, the development of VR systems has matured enough to find its way out of the research realm and into public settings. An innovative example is described below.

3.　　INTERACTIVE VIRTUAL REALITY FOR YOUNG USERS: INNOVATION AND INTERPRETATION

Recent examples of virtual reality research in education have focused on the potential of immersive displays, in order to make the interface for the learning experience easier and more natural to use. The introduction of projection-based VR systems has shifted the format from the one-man VR experience with bulky headsets and equipment to the slimmed down, more comfortable visual displays for multiple people simultaneously. Particularly, the work carried out by researchers at the University of Illinois at Chicago (the Round Earth project: Johnson et al. 1999; Moher et al. 1999; the NICE project: Roussos et al., 1999) looks at the issues involved in the use of projection-based virtual reality systems with children, specifically in the well-known CAVE® VR theater. The CAVE is a multi-person, room-sized virtual reality system consisting of three walls and a floor. All users entering the CAVE wear special lightweight stereoglasses, which allow them to see both the virtual and the physical world unobtrusively, and use a lightweight hand-held device, called a wand, for interaction (Figure 3.) As the CAVE supports multiple simultaneous physical users, up to 10 children can participate in the learning activities at the same time. A similar but smaller VR system, the ImmersaDesk™ consists of one back-projected panel tilted at a 45-degree angle resembling a drafting table (Figure 1).

Figure 1: Children experiencing history with high-end immersive virtual reality.

Following examples of innovative institutions of informal education as described previously, the Foundation of the Hellenic World (FHW), a cultural heritage institution located in Athens, has sought to synthesize the research as formed so far with the actual use of virtual learning environments by students, on a more permanent basis.

The Foundation's mission is to preserve and disseminate Hellenic culture, historical memory and tradition, as well as project the contribution of the Hellenic spirit in the development of civilization. Its main plan for operation is the use of advanced technological methods to promote this understanding of the past, to synthetically and comprehensively present the history, life and values of the Hellenic world in its broader geographical evolution. In the belief that history is a basic ingredient of the present and the future, the Foundation's aim is to communicate with the public in an immediate, vivid way. So it makes the best of contemporary museum theory, developments in computer science, and the use of audiovisual media and interactive exhibits. The FHW's Cultural Center stands on the site of a former industrial area that has been converted into an attractive contemporary complex of buildings covering 35,000 sq.m. in the heart of Athens. The overall design, architectural, electrical and acoustic plans of the complex make it one of the most modern and well-designed cultural centers in Europe. This site houses two projection-based immersive virtual reality systems such as the ones described above, that can normally be found only in research labs, as well as specialized staff to create the programs, thus developing a kind of "VR center" focused on the cultural domain. Not only is this blend of the traditional with the most advanced unique as far as museums are concerned, it is also a one-of-a-kind endeavor for Greece.

VR technology at FHW functions in two basic ways: as an educational/entertainment tool and as an instrument of historic research, simulation, and reconstruction. Examples of applications include an interactive environment that brings to life the magical world of Byzantine costume through an experiential educational world created for children and the reconstruction and journey through the ancient city of Miletus by the coast of Asia Minor, as it was two thousand years ago. In the virtual city of Miletus, participants can "walk" through or fly over the accurate three-dimensional reconstruction of the most important public buildings, "dive" into the harbor of ancient Miletus, explore the city as it unfolds through time, and experience the life of its architectural glory, its people and their customs, habits, and way of life. With the use of the navigational device, children are free to choose their own path in visiting five of the most important public buildings. They can examine the architectural details and landscape from many different perspectives, practice their orientation skills and get understand the sense of scale, proportion, and space used by their ancestors. If they choose to fly close up to the columns, the architectural elements of the 3-D models fade into layers of higher detail, enabling the participants to experience an accurate reconstruction. Our next step in enhancing the educational experience is to add construction ability, where the children can switch between elements and compare the evolution of style through the evolution of time in the city. The use of architectural detail in immersive real-time virtual reality systems is difficult due to the technical and performance restrictions placed by the real-time image generator. Hence, increase in detail and interactivity results in performance decrease that in turn creates a less believable experience. We are technically trying to achieve better performance before we can add the ability for a more constructionist and interactive perspective.

The second program created for young students is the Magical World of Byzantine Costume, the first in a series of short programs created to complement the exhibition on the 4000 years of Hellenic costume currently on display at the museum. The focus in this program is different from the above in that an accurate reconstruction is not sought, rather an interactive, magical experience with less detail and more interactivity is attempted.
Other programs under development include productions to complement or highlight important events that shape our time, culture, or everyday life, such as the Olympic Games and Cultural Olympiad, as well as experimental environments and innovative collaborations with scientists,

universities, and artists, that allow to gain insights on the creative use of technology. Both VR systems are used to present these projects. Particularly, the smaller system based on the ImmersaDesk™ technology is a virtual reality environment "on wheels" that has the ability to move about the museum campus. It thus enables the creation of a truly flexible virtual reality setting for the museum and allows for customization of the virtual reality exhibit to any current exhibition or program.

Figure 2: Young visitors interact with the virtual learning environments created at the Foundation of the Hellenic World's immersive virtual reality systems.

Approximately 500 students visit the virtual reality exhibits daily in groups of 10 or less. The duration of their experience in the systems ranges from 10 to 20 minutes. The numbers are large considering the experimental nature of the technology. However, while the programs and setup can afford unique educational and recreational opportunities, the technology inevitably suffers from a number of drawbacks in terms of usability -- essentially practical problems related to the fragile nature of the equipment: once installed, the virtual reality equipment requires special handling and a specially designed place where metal structures are not present; the display system must be designed to withstand breakage, short attention spans, greasy fingers, and large numbers of excited visitors; the stereoscopic glasses are expensive and can break easily as their sizes are not made to fit children's heads; equipment must be placed out of reach, yet accessible to the technical staff; finally, experienced guides who have both the technical skills and the educational background are always required. These issues are described below.

4.   EFFECTIVE DEPLOYMENT: ISSUES AND CHALLENGES

The introduction of high-end or virtual technologies in educational settings runs up against a number of issues that must be considered. Specifically, interactive learning environments must take into account the physical context of the public space, support the conceptual and aesthetic standards of the learning purpose, and be functional and accessible to its intended group of learners. Whether it's the novelty of interactive technology and virtual reality exhibits

or the compelling nature of the applications themselves, children flock to see things that are new and cutting edge, even if the content remains relatively unchanged. This generates added worries to educational technologists who must design keeping their educational role in mind, yet providing the added novelty, accommodating an increasing range and types of educational experience, and enhancing student motivation. The uniqueness, cost, size, and fragility of VR aggravate these problems. VR technology will be deployed in considerably fewer numbers than personal computers; the existent application base is almost non-existent; there is no standard staff development curricula or off the shelf courseware; and technical support requires very specialized expertise.

Attention can be focused on the following set of issues which previous experience, observation and evaluation studies (Roussos, 1997) have led us to recognize as the more critical ones in the process of introducing highly interactive technologies for learning:

1) Bring technology into context.
Technology can not stand-alone. As both schools and informal learning institutions are essentially public spaces, the physical context of the public space must be taken into account while addressing the specifics of venue and learner group. Effective deployment of technology relies upon the degree to which it can be thoroughly embedded in its context of use, including the ordinary, practical competencies of those who are to work with it.

Students vary in age, level of education, interests, and learning styles. To address these differences, good design recognizes the social activity between them by providing space for more than one person to get involved and by developing interactive media experiences that often serve as prompts for social interaction. Programs should not come into conflict with the natural, often non-linear ways a learner may interact with them. The multi-modal nature of interactive technologies provides ideal ground for the development of flexible tools for both a group experience and the opportunity for personal knowledge.

2) Technology must be seamless.
A well-designed environment is one that is consistent, predictable, and transparent. New media tools are just elements to enhance the educational, informational or aesthetic goals of any given program, and should thus be seamlessly incorporated. Hence, the technology should be designed to "disappear" during the experience, be non-obtrusive, lending focus to the learning purpose at hand.

3) Provide immediate feedback yet prolonged engagement.
Donald Norman identifies four principles of good design that can be applied to an information environment to make it self-explanatory and not frustrating: visibility, a good conceptual model, good "mappings", and feedback (Norman, 1988). The format of a typical learning experience involving technology may inevitably be controlled, structured, and brief. Hence, responsiveness and feedback are particularly important in settings where we encounter only brief interactions. Children expect a response immediately otherwise they lose interest. This may be more difficult with highly interactive environments where interactivity is not easily controlled. Experiential-based installations and participatory environments must demonstrate different strategies to include and involve the participant in the events on a long-term basis. The key is to provide immediate responsiveness and then prompt for deeper involvement from the part of the user. Overall, experience from the use of virtual reality with large groups of

children has shown that the effect can be much more powerful if it possesses two important attributes: an interacting mentor and long-term engagement with the learner.

4) Design with content in mind and involve the experts.
In many cases, high-end technological innovation often creates the suspicion of high cost and low content. Current applications seem unable to step out of paradigms created by other media. "Old media" do not always translate gracefully into interactive media environments, producing in many cases outcome that seems fragmented. It is also often the case that novelty overshadows content. Technological developments may often be associated with disappointing gains for users whereas compelling content will most likely engage the student regardless what the form of presentation may be. As a result, many educators are skeptical regarding the added value and appropriateness of advanced interactive technology applications for learning. Based on the above, it is important to use the involvement of content experts when designing interactive and virtual environments. As difficult as it may be for educators, artists, designers, archeologists, historians, architects, doctors, scientists, or technicians to speak the same language, it is nevertheless essential for the creation of sound and complete environments. Questions should be asked regarding the underlying principles that are guiding the development of content and conventions should be set for structuring and delivering this content. An institution of informal education, in particular, must be more flexible and able to provide the best combination of technological innovation and educational content and create a shared critical context within which to understand the work aside from understanding it technically.

Figure 3: The wand - an interaction device for a VR environment

5) Be concerned about physical and accessibility issues.
Clearly, an important point of particular relevance to high-end interactive technology is usability, which must be considered in the context of hundreds of students who may make use daily. Practical issues and problems are especially apparent when the apparatus is not designed with novice or special users in mind, as is the case with most experimental high-end computer technology. In the case of virtual reality, for example, it is common for most systems to cause motion sickness; active stereoglasses are too large for small heads, too fragile, and too expensive to trust them with any excited visitor, let alone a child; children must use both hands to operate hard-to-use interaction devices, hold the stereoglasses with special ties, or even deploy support systems to stand up higher in order to achieve the correct viewing angle. Good sight lines, ample seating where applicable, comfortable viewing for extended periods, good field of view, and ergonomics are some of the issues that must be addressed when designing a unique interactive learning environment. The interactive experience must also have an easy to

learn and simple to use interface, which is accessible to a wide range of skill levels and requires virtually no student training.

As research in the field continues, we must continue to see that the insights gained through experienced use are adequately translated into the design of educational environments, and both inquisitively and critically examined. No one yet knows what will be successful or how children will ultimately use and interact with these emerging environments - the contours are just now starting to form and become visible. It is thus important to strengthen our efforts and continue to accumulate guidelines that will be turned into a useful resource for sound development and evaluation of interactive technologies for children.

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