Chapter 3

VR as Instructional Technology – The CAVE as Classroom

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Introduction

Kathy Madura is teaching her students at Abraham Lincoln Elementary school in Oak Park, IL about the human heart. Part of the lesson is taught using traditional paper drawings, and plastic models. Part of the lesson is taught on the gym floor that has been layed out as various chambers of the heart and lungs where the students grab red dodge balls and move around the gym floor through the 'heart' and 'lungs' to learn how the entire system functions. The lesson is also taught using virtual reality equipment installed at the school. Kathy and three or four students wearing special glasses stand in front of an ImmersaDesk® a drafting-table shaped VR device with a large 6' by 4' stereo-image screen where a 3D model of a human heart floats. The students can watch the heart pumping and follow the path of blood flowing through the heart and lungs. The students can stick their head into the various chambers and look around, or they can use a virtual 'cutting plane' to see the internal structure of the heart and lungs from any viewpoint.

At the Foundation of the Hellenic World, a museum dedicated to Hellenic culture in Athens Greece, children daily walk through the ancient city of Miletus on the coast of Asia Minor as it appeared two thousand years ago, within a virtual reality room. This room is 10' wide, 10' tall, and 10' deep, with three walls and the floor being large projection screens showing stereo-image computer graphics. When the students put on the special glasses, the city of Miletus surrounds them in 3D. The large display screens allow the students to walk through Miletus, and see all of the buildings full-scale. A human tour guide leads them on a tour of this virtual city in the same way they would tour a real physical place.

These are just two examples of virtual reality (VR) technology being used to enhance conceptual learning in real educational settings. In this chapter I will talk about some of the work being done explore the potential of VR to create effective learning environments.

What VR means to us

First of all I need to define what I mean by 'virtual reality' since many different people have different definitions. The broadest and simplest definition is that virtual reality allows the user to immerse himself or herself in another world. This definition includes 'old' technology such as books, plays, films, orchestra recitals as well as new technologies such as chat rooms, video-conferences, and video games.

However, for people doing research in the area of virtual reality, the definition is more specific. Virtual Reality needs stereo visuals (to see the world in 3D), wide field of view (the difference between seeing a film is a theatre and on TV), viewer-centered perspective (as you move your head or body your perspective changes), a way to interact with the world, audio, and perhaps the sense of touch. The idea is to recreate the experience of being a person in a space, except here that space is an artificial world generated by a computer. For different goals, all of these components (stereo-visuals, tracking, wide field of view, interactivity, audio, touch) may not be required, and a major part of the research right now is seeing which components are valuable for which learning goals.

When most people think of ‘virtual reality’ the common image is a head-mounted display, where the user wears a ‘helmet’ on their head that covers their eyes and ears. We take a different approach and use large projection screens instead. This way the user isn’t isolated from the real world, and more importantly isn’t isolated from friends and colleagues who are standing nearby. The large screens allow multiple people to share in the experience at the same time, which can be very valuable in educational situations where small groups are working as a team. This is also an advantage over standard computer monitors.

There are currently hundreds of VR rooms, and drafting-table sized displays in use around the world. They are most commonly used in research labs for scientific visualization, and in companies such as General Motors for design and evaluation of products in full scale. There are also history museums using them to look at historically significant sites, and even several art museums such as Ars Electronica in Austria and NTT’s InterCommunication Center in Tokyo that have installed these devices to explore their potential as a new art medium. Other researchers are looking at skill acquisition and training, especially in medicine. Our work focuses on the application of these kinds of devices in conceptual learning from elementary school through college. I will describe this further in the next section.

How VR fits into the learning process

We believe that VR can be a valuable tool for conceptual learning. Unlike a textbook or video that presents material in a certain order, in VR the subject matter can be experienced in any order. Unlike a static drawing or photograph, the student can see how the system changes over time, or manipulate the system to see what affect those changes will have. And finally, immersion gives the student the feeling that he or she is directly experiencing and interacting with the subject matter.

Of course this freedom may lead to confusion if the students are left on their own. The teacher is still the most important person in these educational worlds. The teacher guides the student through the virtual experience in the most appropriate way given his/her experience with the subject matter and the student. We see virtual reality as just another tool that the teacher can employ when it is appropriate. Just like textbooks, and filmstrips, and video, and guest speakers, and plastic models, virtual reality technology will be good at helping learn certain concepts. We are investigating where it can be useful.

Virtual reality should be good for investigating 3D objects (such as the human heart) or walking through 3D places (such as Miletus or Virtual Harlem). It allows us to visit places that are too remote, too dangerous, or simply impossible to visit because they no longer exist, or they don’t yet exist. There are less exotic ways to visit such places, through photographs or paintings, or videotape. Unlike photographs or paintings, VR allows the student to see the context of the image - what lies outside the frame, what is behind the camera. For example, we have worked with researchers at Northwestern University to create a virtual world allowing people to walk into some of the caves in the Mogoa Grottoes of Dunhuang China on the silk road. These caves are in a remote location and access is limited because of their fragility. The interiors of these caves are covered with murals, and while photographs are good tools for seeing individual murals in detail, VR is a good tool for allowing a person half-way around the world to stand inside one of these caves, surrounded by the murals, and see how the murals relate to each other. Unlike videotape, we have control over where we move and what we chose to focus our attention on.

VR should be good when the user can learn by manipulating the virtual object or scene and seeing the resulting effect. VR allows us to see things at the appropriate scale – where that is full scale for Harlem, or making ants and atoms large enough to see, or making our solar system small enough to see. VR allows the user to 'become' someone or something else with different abilities, or characteristics – such as a bird that can fly, a red blood cell flowing through the bloodstream, a person with a vision problem, or someone from a certain ethnic and social background in Harlem. We have the ability to connect these VR devices together, linking students around the country or around the world. We also gain the ability to record what the student does in the virtual world – where did they go, what did they interact with? This allows the developers to improve the virtual world, but it also allows the teacher to see where the students spent their time and what they experienced, which can be very difficult in the real world. This form of embedded assessment may be very useful in gauging learning effectiveness.

Since this technology will remain exotic for a while, we need some way to allow the students to take something tangible away from the experience – an artifact, to aid in reflection later on. These may be drawings they made based on their observations in the virtual space, or pictures taken within the virtual environment. We can also generate lesser-tech versions of the virtual experience, say by making a video of what a typical user would see in the environment, or by taking snapshots of what that typical user saw in the environment and then making those available on the internet or CDROM. This would allow us to link together a museum experience, a school experience, and the home experience. Conversely, we would like the students to be able to leave artifacts within the virtual environment (Bricken 1993). In Virtual Harlem the students can leave annotations in the space, becoming another character in the virtual world (see Kyoung's section).

Technologically this is all doable today. However, it is important for us to learn from the lessons of past attempts at integrating technology into educational settings, most of which have been unsuccessful. We must address the needs of the individual learners while respecting the constraints (financial, time, and space) imposed by the educational context where learning occurs; and those constraints are very different in an elementary school, a museum and a university. Just showing that the technology works isn't enough. For it to be truly useful we need to show that it is valuable in real educational settings with real students and real teachers. The next section will describe some of the research that we are doing in those real settings.

Current projects

There are several different groups doing research into using virtual reality in conceptual learning in museums, universities, and K-12 classrooms [Youngblut 1998], [Dede 1996], [Rose 1995], [Gay 1994], [Allison 1997]. There is a lot of work to be done in this area, and many different approaches to be tried. In this chapter I will concentrate on the work that I am most familiar with. At the Electronic Visualization Laboratory at the University of Illinois at Chicago we have been focusing on assessing the impact of VR in an elementary school, but also doing projects for museums and university courses. This work is a large collaborative effort with the main faculty members involved being Tom Moher and myself from Computer Science and Stellan Ohlsson from Cognitive Psychology.

One of the difficulties in assessing the impact of these VR learning experiences is that it is difficult to separate the virtual world from the technology that delivers it. Ideally we want the student to focus on the lesson to be learned, not the big screen, or the 3D glasses; we want the technology to fade into the background. However the novelty effect of VR technology is quite strong because it is exotic. Only through repeated use will the technology become 'invisible.' One of the main reasons that we have moved an ImmersaDesk into Abraham Lincoln elementary school was to try and avoid the novelty effect by giving the students multiple lessons using the VR technology over several years. Of the current children at Lincoln Elementary, roughly all of the 1st, 2nd, 4th, and 6th graders and one quarter of the 3rd graders (over 425 kids total) have had at least one VR experience over the past 3 years. Over 100 students have had 2 or 3 different experiences over the last three years.

Our main topic of study in the elementary school is this coordination of multiple representations, both within the virtual worlds, and between the virtual world and other media. In order to truly learn a concept, students need to make the appropriate mappings between representations given in different media, and different representations within the same media. As described above, VR gives us opportunities to present more appropriate representations in certain domains. How do help the student correctly map between those representations? In our work in the elementary school we are investigating this through three tracks of research [Johnson 2001].

In the 'round earth' track we are trying to help 1st and 2nd graders learn about the shape of the earth, and create the mapping from the apparently 'flat' Earth they walk on and the 'round' Earth seen from space. This is more than just being able to say that the Earth is 'round' or has the shape of a sphere. It also means knowing about the ability to circumnavigate the Earth, the relativity of up and down, the lack of support for the earth, and how the Earth's surface occludes things on the surface that are far away. These things are hard to learn on the small patch of the surface that we commonly walk on every day, and in fact that experience gets in the way of trying to learn about the true shape of the Earth. Instead of trying to convert their existing flat model into a spherical one, we use VR to take the children to a small round asteroid, like Antoine de Saint-Exupery's Little Prince lived on. VR helps the kids believe that they are really walking on this small asteroid where they can learn about what its like to walk around on a small spherical body. Then with the help of a small Styrofoam model and a Earth globe, we talk to them individually about how the earth is the same, only bigger [Ohlsson 2000].

In the 'virtual ambients' track we are trying to teach the kids about the scientific method by giving the kids a virtual field to explore and tools to collect data. This gives them a similar experience to going out to a nearby field and collecting rocks or insects, but here the teacher has control over what they find, so we can make the word simple for younger children and progressively more complicated for older children. This is similar to an archeological dig my class did in the 6th grade in a nearby field – of course the teachers had gone their six months earlier to plant all of the broken objects we would find. In our virtual field the children can learn how to survey a space, and collect data to analyze, then they should be better at doing the same tasks in the real world. Here the mapping we are concerned with is the mapping between objects/phenomena (plants, rocks, animals) and their abstract form as data (points, numbers, symbols). We believe that going through the act of collecting the data (in our case surveying a virtual field and taking measurements on the plants found there) makes it easier to follow that data through the analysis process, rather than just starting with a set of numbers which is already an abstraction. Small groups of 3 or 4 students spend about 30 minutes collecting data in VR; the rest of the lesson (planning the data collection, integrating the data, analyzing the data) is done as a whole-class activity over several hours [Moher 2000]. See figure 1.

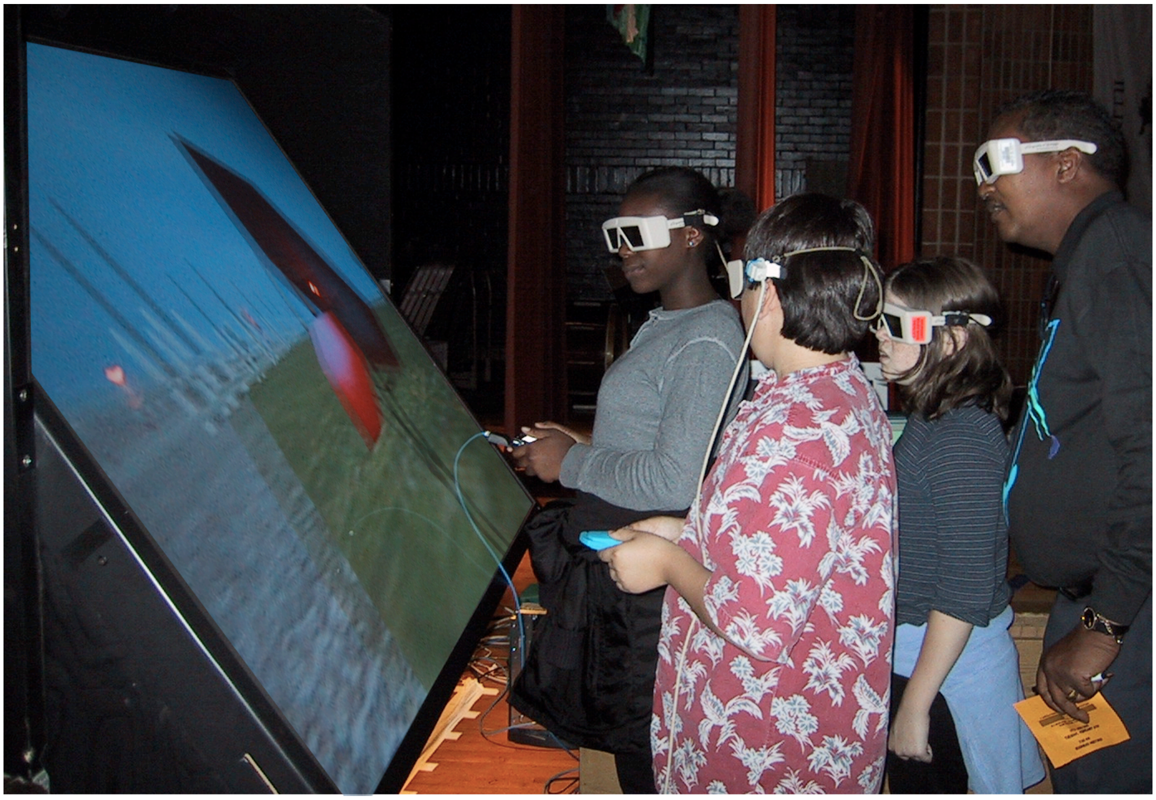

Figure 1 – Sixth grade teacher Kevin Harris watches as three of his students explore and collect data from a virtual field

In the 'quickworlds' track we are looking at how this technology can be easily integrated into existing curricular units. Here the teachers ask us for simple virtual worlds and we build them – for example the beating human heart and lungs described in the introduction, or an ant with internal organs, or the solar system – things where VR should be useful in learning the concept. We want to observe how the teachers, such as Kathy Madura, relate their traditional methods of teaching to what can be experienced through VR [Johnson 2000]. See figure 2.

In Virtual Harlem we are dealing with similar issues of coordinating multiple perspectives. The students are already getting different perspectives from the various authors they are reading, the photographs they are seeing, and the music they are listening too. The virtual environment gives them another perspective – richer in some ways, poorer in others. Like the Round Earth work, we are trying to immerse the students in another environment – taking them out of the classroom and onto the streets of Harlem 80 years ago. Live the Virtual Ambients we to give them a world to be inquisitive about, a place that encourages them to ask questions about the people and the places in the Harlem Renaissance. Like the QuickWorlds we want to try and integrate this new technology into existing curriculum where appropriate to see what benefits it may have.

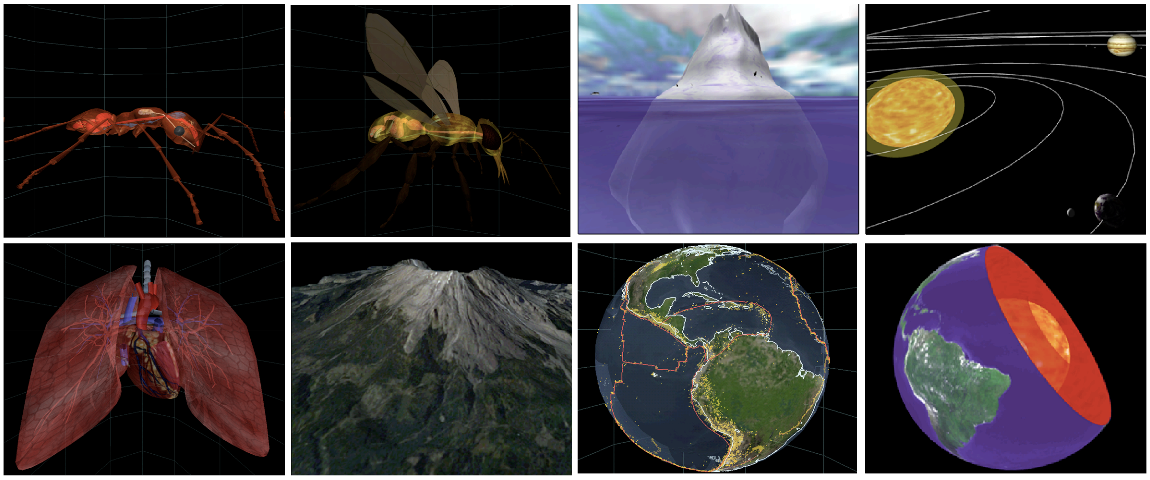

Figure 2 – A selection of QuickWorlds that we have developed for the teachers at Abraham Lincoln Elementary School – clockwise from top left: an ant, bee, iceberg, solar system, interior of the earth, earthquakes and plates, Mt. St. Helens, and a human heart and lungs

What we are learning from these studies

By placing this technology in real world setting we can see what works and how to adapt our procedures when things don't work. This section will discuss some of the broader lessons we have learned from these deployments at Lincoln.

Usability hasn't been a problem, especially for children; first graders can successfully use the technology. In general, younger students are more comfortable with the technology – they are already familiar with videogame controllers, and they are less inhibited when it comes to exploring the virtual worlds. This can be a good thing or a bad thing. The children are motivated by exploring the virtual world, but its easy for them to treat the virtual world as a game and not stay focused on the learning goals. The guides and teachers need to keep the students focused, and engaged not just with the superficial aspects of the environment, but with the deeper lessons it is helping to convey.

While children are moving and looking around and seeing what they can discover in the virtual world, adults tend to stand very still and move very little. Adults tend to be less comfortable with the technology. This can be a problem, especially in college classroom settings where we need to provide an equivalent experience to those who do not want to participate in the VR experience. Here it can be very helpful to have lesser-tech versions of the virtual worlds available.

We have found that it is hard to measure changes in the student's knowledge. This shouldn't be a surprise since there is no agreement in the education community on how to assess this. We pretest and posttest the students in the Round Earth track, and we don't just give them a written test, we talk to them and try and probe for the reasons behind their answers. We talk to the teachers in the QuickWorlds track. We videotape the classroom discussions and the VR experiences in the virtual ambients track. We have found that the Round Earth experience did bring the students who didn't have a solid grasp of the sphericality of the Earth up to the level of their classmates that did. We are still investigating how much of that is because of the VR and how much from just talking to the children – our initial results suggest that the VR asteroid is better at helping children gain some concepts and the Styrofoam asteroid is better at others.

The most important lesson has been about accessibility. If the technology isn't easily accessible, then it won't be used. In the elementary school we have found that its not enough to be in the school – we need to be in individual classrooms. In museums this isn't a problem, but it can be at a university. Typically these high-end VR devices are located in research labs, not in lecture centers so instructors need to hold their classes in a different place to make use of the technology (as was the case for the Harlem Renaissance classes at UIC in the spring of 2001.) We also need to investigate what the right technology is for each situation – should students interact individually, in small groups, or as a whole class? The larger the class, the more likely it is that students will participate in larger groups, but that is currently driven by the exotic nature of the technology.

Right now this kind of VR equipment is still very expensive, but as with all computer technology, the power is increasing as the cost is decreasing. Where a couple years ago we would have used a $250,000 computer to create our virtual worlds, we can now get fairly good performance from a $5,000 computer, which brings the cost of a large screen VR display (including tracking) down to $25,000. This allows us to build systems like the AGAVE (cite kyoung's section) for the in-class Virtual Harlem demonstrations, as well as a portable plasma panel which we roll between classrooms at Lincoln. See figure 3. The cost is decreasing at the same time that most universities are wiring up their lecture halls as multimedia rooms; the technology is converging nicely.

Figure 3: Three students at Lincoln elementary work with a lower-cost version of the technology – a 50" plasma panel driven by a consumer-level PC which has been rolled into their classroom for a week.

So far our investigations of VR as a conceptual learning tool have been encouraging. We believe it is helping the children at the elementary school, and perhaps more importantly the teachers and principal believe that it is helping. We have just begun our work evaluating how Virtual Harlem can be useful. Here we have a different group of students, in a different educational context, learning different subject matter. We are also learning. We are learning how to make better virtual environments, and better educational interventions that take advantage of VR.

Acknowledgements

As with the work on Virtual Harlem, the work going on at Lincoln Elementary is a large collaborative effort with people from several disciplines: Tom Moher and Jason Leigh from computer science, Stellan Ohlsson from psychology, Josh Radinsky and Mark Gillingham from education; and all grad students from computer science, art, and psychology: Yongjoo Cho, Ya Ju Lin, Dave Pape, Mark Orr, Joseph Alexander, Josh Hemmerich, Alex Hill, Janet Kim, David Haas. We would also like to thank Carol Dudzik, the principal at Lincoln Elementary, as well as the students, staff, teachers, parents, and students for their support and encouragement during this work. And thanks to the National Science Foundation for supporting this work through several grants: EIA 9720351 - Deep Learning and Visualization Technologies, DUE 9979537 - UIC Graduate Fellows in K-12 Education, BCS 9907839 - Prior Knowledge, Analogical Transfer and Multiple Perspectives in Child Learning, EAI 0085946 - ITR: Learning-Centered Design Methodology

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