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Deploying VR in an Elementary School - Pipe Dreams and Practical Realities

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Abstract

This paper discusses the practical realities of maintaining a projection-based VR learning environment inside an elementary school, in terms of supporting the VR resource, and integrating it into the school culture. It also presents several of the lessons we have learned in the first year of this deployment.

1. Introduction

In 1997, the NICE group and the Round Earth group conducted VR-based learning studies with over 80 elementary school children within the Electronic Visualization Laboratory at the University of Illinois at Chicago. It became obvious that a much better solution would be to conduct these studies within an elementary school itself [6]. In December 1988 we moved an ImmersaDesk® into a classroom at Abraham Lincoln Elementary School in Oak Park, Illinois for a month-long research project with 76 second graders [3].

In August 1999 we returned to Lincoln on a more permanent basis, moving an ImmersaDesk into a room adjacent to the school's media center where it will remain for three years to continue our research into learning and pedagogy. In the broad sense we are asking two questions: First, can VR be a valuable learning tool for elementary school kids? and second, can VR be effectively integrated into the culture of an elementary school?

Specifically, the VR resource is being used for three tracks of research. The first is looking at how VR can be valuable of in the coordination multiple mental models – a continuation of the Round Earth project. The second, Virtual Ambient Environments, is investigating how VR can be used as a data collection medium in learning about the scientific process. The third, QuickWorlds, is making the technology available to the teachers to see how they would use it in their existing curriculum. The first involves individual students using the VR equipment, while the second and third involve groups of children; projection based VR is ideal in this situation as it allows us to deal with both.

Lincoln is a K-6 elementary school in Oak Park, Illinois, a racially and economically diverse inner-ring suburb bordering Chicago's West Side. Lincoln is attractive as a research site for its size, diversity, and state of technology adoption. It is a large school (620+ students), nearly always allocating four (20-30-student) classrooms at each of the K-6 grade levels. Besides a racially and economically diverse student body and faculty, Lincoln offers diversity of subject mastery, as reflected by IGAP (Illinois Goal Assessment Program) and Stanford-9 achievement tests administered at the school. While performing moderately above average as a school, Lincoln has significant representation in all performance quartiles. The school is also about average with respect to technology infusion, with about one computer for every five children, distributed both in classrooms and a computer lab, with an orientation more toward computer literacy and technology education than conceptual learning.

Why work with elementary school kids? During some our previous educational VR studies conducted in the laboratory, we could see dramatic differences in young children from advantaged and disadvantaged backgrounds. As such, elementary school is the place where we believe we can have a major impact. Why work within a public school? Within a few years we believe this kind of technology will be available to those with means. If it is to be a technology that helps reduce the technology gap, rather than broadening it, then it has to be available to a wide range of students – and that means the public school system.

Currently this technology is too expensive for public schools, and their money would be better spent on reducing class size and buying more supplies. However the cost of the technology is coming down rapidly, and pilot projects such as this one could help point the way towards effectively integrating this technology when it is cost-effective to do so. We are not looking at what would be an appropriate cost-effective VR setup for a school today. We want to investigate where VR could have a positive effect in elementary school education.

Figure 1: Photograph of the ImmersaDesk in a room next to the Media Center at Lincoln Elementary School

As such we are not limiting ourselves to slower, less powerful, less expensive equipment. We want to have high frame rates and detailed virtual worlds to give the technology the best chance of succeeding. This means throwing some very expensive technology at the problem to find what works and what doesn't. We want to find out which components of VR (wide field of view, head tracking, hand tracking, stereo visuals, audio, etc) are important in this endeavour, and how to leverage them effectively in the context of an elementary school.

Simply making this technology, or any technology, available in the elementary school doesn't mean it will be used, or used effectively; the history of meaningful technology adoption in schools has been discouraging [2]. We are not investigating VR as a stand-alone solution. VR technology is not going to have an impact on its own. We see VR like textbooks, or filmstrips, or building blocks. It is another tool that the teacher can use when it is appropriate to do so, in combination with other tools, to aid learning.

There have been several previous and ongoing efforts at using projection based VR with children and young adults. The 'crossing streets' work at NCSA used a CAVE ® to help teach handicapped children how to safely cross a busy street. In 1996, the 'cyber mummy' work at NCSA allowed 24 6th graders study the scans of a mummy in the CAVE. Since 1998, Indiana University has encouraged groups of 10 to 15 high-school students to create virtual worlds and then visit them using an ImmersaDesk during a week-long VR summer camp. Iowa State University has broadcast a VR tour over the state's fiber optic network to schools in the state. Since 1999, the Foundation for the Hellenic World has used VR as a regular part of their museum experience.

There have also been several previous and on-going efforts using HMDs with children [1, 7, 8]. While HMDs would be valuable in situations where complete 3D lookaround is necessary, we want to have multiple children simultaneously experiencing the virtual world with their teacher. Learning in an elementary school is a social activity, and we believe a projection based system creates a more appropriate social environment. Also, since HMDs are fully immersive, while the ImmersaDesk is semi-immersive there should be less chance of simulator sickness with the ImmersaDesk.

2. Deploying the VR Resource

We slowly worked up to deploying the ImmersaDesk in the school. In the early fall of 1998 we met with the principal and several of the teachers at EVL to talk about the Round Earth study that we wanted to run in their school. This gave us a chance to show them the equipment, show them the software, and let them meet all of the people who would be conducting the study in the school. This led to our deploying an ImmersaDesk, in one of the classrooms at the school for the month of December 1998. That session ran very smoothly and both the research team and the staff and teachers at Lincoln wanted to continue the relationship.

In the spring of 1999 we discussed moving into the school on a more permanent basis. The major issue was finding a permanent space. The staff and teachers were interested enough in the work to make space for us. The physical location of the ImmersaDesk in the school was determined in consultation with Lincoln administration and staff, and was designed to minimize the impact of 'pull-outs' from regular classroom activity. Since classes regularly visit the school's Media Center, its possible to 'pull over' students to work individually or in small groups while the rest of their class is doing other activities in the Media Center, instead of doing 'pull outs' from regular class time. Since the Media Center has its own instructor, the teacher can accompany his or her students in the activity at the ImmersaDesk while the media center teacher works with the rest of the class.

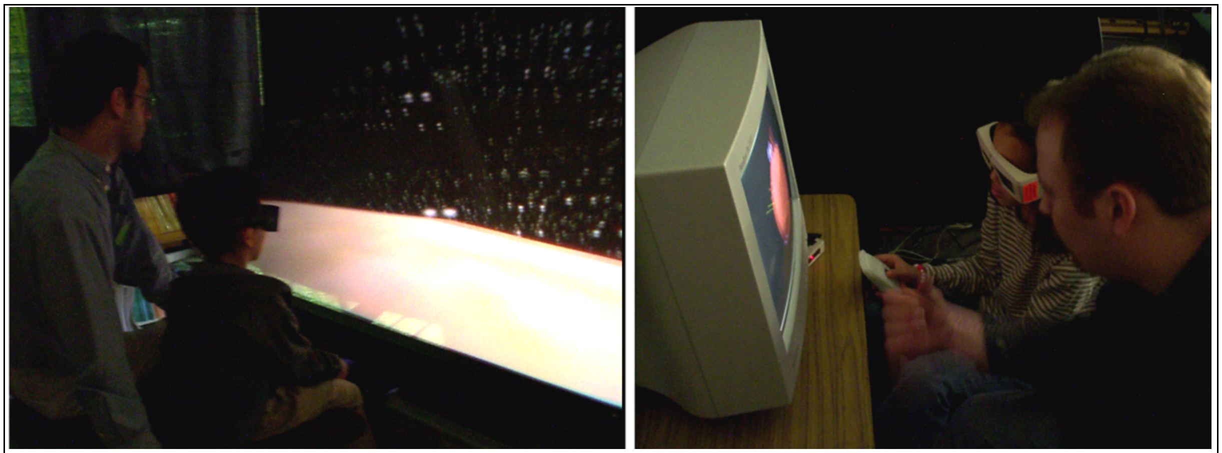
Figure 2: Photographs of two first grade students and their guides collaborating in the Round Earth project at Lincoln

The current equipment in the school consists of an ImmersaDesk driven by a 4-processor SGI deskside Onyx IR, and a 19” stereo monitor driven by a dual processor SGI Octane. While most of the work takes place at the ImmersaDesk, the Octane allows us to continue our work on collaborative virtual environments, and specifically those with heterogeneous views of the same space. It also provides a backup for the Onyx. See figure 1. We run both screens at 1024 x 768 in 96Hz stereo. Both computers are capable of sending audio to the ImmersaDesk’s speakers. When we are conducting more formal learning studies we bring in recording equipment such as cameras and microphones.

After we moved the equipment into the school in late August 1999, we spent the rest of fall meeting with the teachers, with the district’s Parent Teach Organization, and with the school district’s technology council to describe our work, demonstrate the hardware and the software, and answer any questions. Our goal here is to be partners in this effort with the teachers, staff, and parents at the school, so we want them all to be fully informed about what we hope to accomplish together.

In addition to showing our own virtual worlds, several other research groups have allowed us to show their worlds in the school. These worlds have been very important in giving the teachers and staff an idea what the technology is capable of, and how they might be able to take advantage of it. These worlds include CAVE-5D from Old Dominion, Cyber-Mummy from NCSA, the Virtual Temporal Bone from UIC’s VR-Med Lab, Ancient Miletus from the Foundation of the Hellenic World, and Virtual Harlem from the University of Missouri. There were some worlds that we specifically did not bring, such as Cave Quake. While I’m sure the kids would have loved it, we figured they probably have enough artificial violence in their lives, and we didn’t VR to be perceived as just a big fancy video game.

3. Using the VR Resource

The most important definition of reality in an elementary school is the school’s master calendar which describes which classes are on field trips or scheduled for gym or art. All activities in the school must conform to that calendar. This master calendar defines the playing field. The two most important rules on that field are safety and fairness.

Safety issues are of the highest importance. All of the students that wish to participate, and their parents, sign permission slips beforehand that describe the VR hardware and the children’s role in the experience. We have seen a very high return rate on the permission slips and believe this is due in large part to our commitment to educate the staff, teachers, and parents about our work.

Before each VR experience we talk with the children for about 5 minutes, describing the VR equipment to them and answering any questions that they may have. We tell them that some people do feel sick when using it and try to find out if any of the children get car-sick or have trouble at OmniMax movies, so we can watch those children more carefully. We also try to make sure the kids understand that if they want to stop at any time, for any reason, that its all right. During the experience, we regularly ask them if they are having any headaches or nausea. If the VR experience is going to last more than 15 minutes, we have the kids to stop every 10 or 15 minutes to take a break for a minute and remove their glasses and step away from the ImmersaDesk.

The second most important issue is fairness. We are committed to making sure that every child in a selected classroom that wishes to participate, and has permission to participate, can participate. If we choose one classroom at a given grade level for a study, we try to ensure that all of the other children at that grade level have a chance to participate in that study or another VR study. Our ultimate goal is to give each child at the school at least one VR learning experience per year, and we are currently on target to reach that goal.

The children, of course, have been very excited about the technology. Part of the reason for the long-term deployment is to overcome the novelty affect. We would like to see how the kids behave when it's the 4^{th} or 5^{th} time they have worked with the ImmersaDesk. The children will then be focusing less on the technological glitz and more on the lessons it is helping to augment.

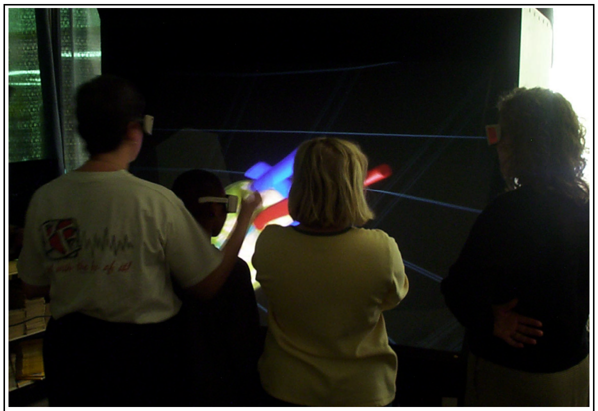

Figure 3: Photograph of Kathy Madura, physical education teacher at Lincoln, showing some of her students a 3D beating heart on the ImmersaDesk as part of the school's unit on the heart.

4. The Virtual Worlds

With our three tracks of research we are supporting three different types of VR experiences: individual learners, small groups and whole classrooms.

- The Round Earth track [3] involves conducting in-depth learning studies with an entire grade level of individual learners. Our first study at Lincoln showed a significant improvement in the children who went through the VR experience and the subsequent dialogue. This year we are studying the relative importance of the VR experience and the dialogue in that learning. This type of study takes several weeks to complete the pretesting, VR experience and posttesting. It requires a high level of commitment both from the teachers and the researchers, as it involves pulling out each student from class three to four times. During the time the children are pulled out of class, they are interacting with the VR technology and the researchers, but not their usual classroom teacher. This creates good conditions for a study but is not very realistic in terms of common school usage. Figure 2 shows two first graders collaborating in the spring 2000 Round Earth study at Lincoln.

- The QuickWorlds track [4] involves a teacher bringing several of his or her students to the ImmersaDesk for 15 to 20 minutes to view an interactive 3D model as part of an existing curricular unit. Depending on the number of children per group, five to eight sessions may be needed for all of the children in a class to participate. In this track the teacher is controlling the virtual experience and the researchers remain in the background as much as possible, as shown in Figure 3. The teachers request these models themselves and tell us what features are most important for them. We then build the virtual models and make them available at the school. Several of the QuickWorlds we have made on request from the teachers are shown in Figure 4. We wanted this track to require a minimal commitment from the teacher. It focuses on the ImmersaDesk as just another presentation medium for the teachers to use, and we are interested in observing how they use it.

- The Virtual Ambient Environments track [5] uses VR as a small part of a larger full-classroom unit where the students survey a large virtual space and then integrate their data. The entire class begins by deciding how to survey the space, then the class breaks into groups of three to four students and each of those six groups spends 20 minutes in VR surveying their piece of the virtual world. After the VR experience there are two more hours of class time to convert their collected data into symbolic representations and discover the 'rules' of the space. Here the experience combines work with the classroom teacher and the researchers, and tries to more directly investigate how to use VR as a classroom activity. Figure 5 shows a group of sixth graders surveying their piece of the virtual world.

The worlds that we are designing for these studies are created in a collaboration between Computer Science, Psychology, Education and Art. We are focusing on virtual worlds where VR should have a direct benefit over existing visualizations (pictures in textbooks, videos, and physical models.) One of the most important issues in creating these worlds is to make sure that they focus the child's attention onto the learning goal, and limit any potentially distracting elements.

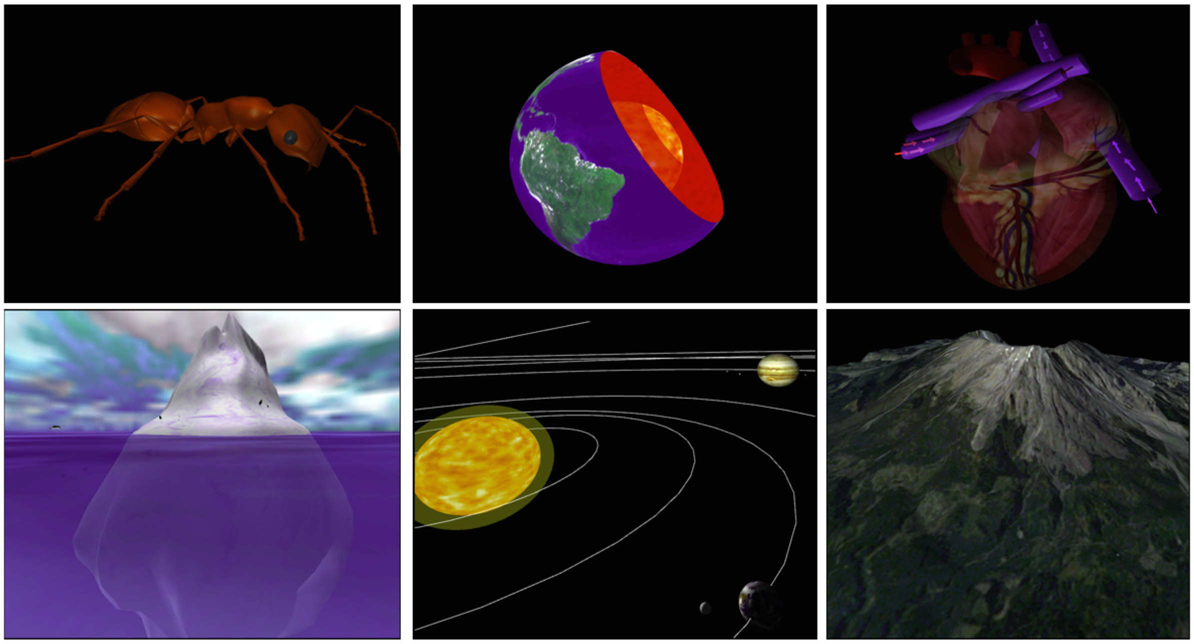

Figure 4: A selection of QuickWorlds that were developed in the first year at the school. Top row: a wood ant with internal organs, the interior of the Earth, and a beating human heart showing blood flow. Bottom row: an iceberg, the solar system, and Mt. St. Helens before and after the eruption.

While the worlds for the in-depth studies take several months to design and implement, our goal for the QuickWorlds is a two to three week turnaround time. The QuickWorlds application is basically a large 3D model viewer allowing the building of each world to focus exclusively on creating the models. The user can then load the appropriate model in, animate it, and navigate around or through it. We also added a generic cutting plane, allowing the user to dynamically slice through the model to see the internal structure.

We wanted to keep frame rates over 20 frames/sec to reduce the chances of simulator sickness. This meant limiting the QuickWorlds to roughly 40,000 textured polygons so they would run very smoothly on the deskside Onyx, and could be run on the Octane if necessary.

We had hoped to be able to leverage the large number of models that have been made available on the web for our QuickWorlds. Unfortunately we found very few models that were appropriate in this context, and even fewer that were freely available. As such we have built all of our QuickWorlds models ourselves so far.

5. Some Lessons Learned

In this section I will discuss some of the lessons that we have learned from this deployment.

5.1 Issues with the User Interface

- The StereoGraphics® glasses we use, both the older fixed earpiece kind and the newer kind that activate when opened, are too large for elementary school kids (and for some adults). An effective solution to this problem even for 1st graders has been to tie sport-bands onto the earpieces of the glasses and then tighten the glasses once they are on.

- Many of the children are familiar with using videogame controllers. As such they had an easy time using the buttons on the Wanda® we are using as our main interaction device, but had a harder time with the isometric joystick. They also tended to treat the Wanda as a two-handed controller, like a videogame controller, rather than a one-handed tracked pointing device. Typically we have used the joystick on the Wanda for movement and the buttons for actions within the environment. Since the Wanda has only three buttons, its not easy to map movement onto the buttons. Because of this we have been investigating the (now discontinued) space-orb, since it has four buttons in a diamond for movement as well as additional buttons for actions, though the spherical orb itself is very difficult for children to use. Ideally we'd like to use specific physical input devices targeted to the particular application, but right now the breadth of activities at the school makes this difficult.

- The ImmersaDesk was designed for adults to stand or sit in front of, and as such it is rather high for younger children. Also, children grow very quickly between 1^{st} and 6^{th} grades giving us a wide range of heights we need to accommodate. Having a set of risers available, or having the younger children sit on a table solves this problem rather easily. See Figure 2 for a first grader sitting on a table in front of the ImmersaDesk, and Figure 5 for several 6^{th} graders standing in front of the ImmersaDesk.

- Since we often have four children and their teacher in front of the ImmersaDesk, we have found it useful to mount an extra IR emitter on top of the ImmersaDesk aiming downwards to augment the two emitters aimed upwards from the inner sides of the ImmersaDesk. This allowed the children to move around without occluding the lower emitters.

Figure 5: Photograph of four 6^{th} graders exploring one of the virtual ambient environments to collect data. Afterwards, they will then return to their classroom and integrate their data with the data of other groups

5.2 Issues with Tech Support

- Having a dedicated room in the school is a very good thing. This allows us to control access to the room, lighting, and noise levels. We didn't have to do very much work to the room aside from hanging drapes in front of the windows. One major problem is heat / air circulation, as the computers produce a lot of heat. Having air conditioning is a must if the equipment is going to be run regularly. We have tried to make the room as non-threatening as possible for the kids by either moving cables out of sight or taping them down. We also try and make sure any extraneous technology is out of sight as the kids are easily distracted by microphones, cameras, etc. Unfortunately for us, the Media Center is on the second floor of the school, and the school has no elevator, so we did have to disassemble the ImmersaDesk into three pieces to carry it up the stairs and reassemble it in the Media Center.

- One of the advantages to having the equipment in the field is that the hardware and software setup remains constant, unlike in a laboratory situation where several different groups may be upgrading various hardware and software components, so we have high confidence in the equipment in the field. Unfortunately the disadvantage of this is that when software is upgraded in the lab it must be independently upgraded at the school, but we have limited those upgrades to once per term. Whenever we upgrade our educational software, we bring it to the school using jaz cartridges since they are large enough and the SGIs can mount them easily.

- It is important to have a system-savvy person at the school while the equipment is in use. This person is responsible for turning on the equipment, start up the application, change batteries in the glasses, and make sure that the devices are working. However this person does not need to be intimately familiar with the hardware or software, as long as there is an expert available by phone. We have run several weeks worth of experiments with psychology grad-students running the equipment in the school without incident.

5.3 Issues with Simulator Sickness

- So far we have had one serious case of simulator sickness out of over 200 children that have experienced the ImmersaDesk in the school. This child was in a group of four children and was not being tracked when she became ill. We found out later that this child was susceptible to car sickness and had trouble at OmniMax films. Interestingly enough this incident did not dissuade any of her classmates from taking their turn. We also had one other student who was interacting alone with the ImmersaDesk. She had no trouble using the non-tracked glasses at the stereo monitor, but decided to stop as soon as she put on the tracked glasses at the ImmersaDesk. In both cases it seemed like the large amount of sudden movement covering their visual field overwhelmed them. In general we have tried to stay away from high vection imagery in these virtual worlds to reduce the possibility of sickness. We have focused on large open spaces, slow navigation, and high frame rates. Because of these incidents we have also created a set of heuristics for head tracking which are described next.

- We have adopted the following strategy for head-tracking. If we have one child in front of the ImmersaDesk, then that child is head-tracked. If we have a teacher leading a group of kids at the ImmersaDesk then the teacher is head-tracked to give the children the most appropriate view. The teacher also knows not make sudden head movements. If we have several kids in front of the ImmersaDesk then we turn head-tracking off since this avoids the intrusion of regularly exchanging the head-tracked glasses, and keeps the image stable. We have noticed several times, though, kids who are not head-tracked acting like they are tracked, trying to look around virtual objects; so there is clearly an interest in being tracked. Our goal is balancing that interest with safety.

5.4 Issues with Working with Children

- Since most, if not all, of the kids are familiar with videogames, they can quickly master the physical controls, and soon come to understand the logic of the virtual world. Unfortunately they are very good at compartmentalizing that knowledge as the rules of the virtual world rather than something that could be applicable to the outside world. Its very important to have a teacher or guide involved to show them how the things they are learning in the virtual world apply to the real world as well.

- Even with the children's experience with videogames, most of them found the ImmersaDesk and its virtual worlds to be quite impressive: 'Sweet!' being the most common comment. Several students also favourably compared the experience to their Sony Playstation®, but of course they wanted to know if we had more games.

- Seeing a stereo display is new to the children, so its sometimes hard to be sure that everyone is actually seeing stereo. Since the kids don't know exactly what they 'should' see, sometimes they don't tell you right away that they aren't seeing stereo.

- Many of the children not only enjoyed the VR experience, but also the pre-testing and the post-testing. We assume this is partly because they are out of class, but also because it gave them a chance to interact with an adult one on one.

- Trying to access the children's' knowledge is difficult. Younger children may not have acquired the necessary vocabulary and the modality of the questions also has a strong affect on their answers. In the Round Earth work we are asking questions verbally, on paper, and using 3D models. While the paper questions are the easiest to record they tend to give the least useful information when dealing with understanding of 3D concepts.

- An important issue in designing these worlds for young children is understanding what the children of a certain age are capable of accomplishing cognitively. Physically, first graders are capable of using the VR equipment, but they may not be able to perform the mental tasks required. The tasks need to be appropriate for each age group, and there is a large variation among individual children of the same age. The literature on child development is a good starting point, but pilot studies are the only way to know for sure.

5.5 Issues with Working in the School

- Having a prior relationship with the school was very important. In our case one of the team members had been a parent at the school and a member of the school board. That personal relationship allowed us quickly establish a good working relationship with the teachers and staff.

- While we initially hoped to pull students over from the Media Center, we have mostly relied on pull-outs from class since the students' time in the Media Center is generally limited.

- Doing these studies in the school is much easier than doing them in the laboratory. Aside from being more realistic, they take fewer personnel, have higher throughput, and require less effort.

- In our first full term at the school we have focused more on the Round Earth and the Virtual Ambient studies than the QuickWorlds. Building the QuickWorlds is pretty straightforward, however limiting our presence at the school to one day per week has made it hard for the teachers to use them. With extra personnel available at the school in the fall we will be in a better position to evaluate them.

- Perhaps the most important lesson we have learned is that its fun to work in an elementary school, and that the excitement of the children is contagious.

5. The Future

Currently we are spending one day per week at the school to support the QuickWorlds, and performing three large studies (Round Earth, and two different versions of Virtual Ambients). In the fall we will be expanding our QuickWorlds time and continuing the large studies. At this point, after one full active term at the school, we are a familiar part of the school and over half the teachers have interacted with the ImmersaDesk. However it will take us several more terms before we are seriously integrated into the school culture.

During our initial presentations to the teachers, the PTO, and the school district's technology council there was interest in learning more about the technology and how it could be used. To satisfy this need we will begin offering courses for teachers on how this equipment can be used at the school. This will help us bring the teachers more deeply into our work as research partners rather than just consumers.

Our current plan is to leave the ImmersaDesk at Lincoln for three years. At the end of that time we hope to have answers to our two main questions – whether VR can aid in elementary school education, and whether VR can fit into the culture of an elementary school. If the answers to both of those questions is 'yes', and the staff and teachers at Lincoln want to continue this work, then we plan to remain at the school. We may also try and expand the research to a couple other schools in the area – either to another elementary school, or to one of the junior high schools, or the high school.

Also, at the end of these three years we will be in a better position to speak about the relative value of large screens, stereo, and tracking. This information, combined with the results from other groups, will inform the kinds of systems we might install in the other schools.

At that time we want to be in a position to describe an appropriate 'low cost' system. The virtual environments used in our studies can run off of a Linux box, and EVL has been investigating rear-projected passive polarized stereo with its lighter glasses, as well as continuing or investigations into plasma displays.

Currently we have a VR setup that is appropriate for small groups of learners in a specific room. The children can visit this 'VR room' just as they would visit the music room or the art room, and the VR device itself acts as a shared resource such as students commonly find in chemistry or physics classes in junior high to high-school. Other options we are investigating include large projection screens suitable for an entire classroom which could be placed in the auditorium, or a smaller device that could be moved into an individual classroom. Right now the ImmersaDesk gives us a nice compromise to begin these investigations.

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