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The Round Earth Project

Collaborative VR for Elementary School Kids

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This paper discusses the deployment of a collaborative VR environment in an elementary school to help teach children that the Earth is spherical.

The concept of a spherical Earth and the implications of that fact are well-represented in the AAAS Project 2061 *Science for all Americans* report and the difficulty of teaching it has been documented by Nussbaum, Vosniadou and Brewer [3,4]. The concept of a round Earth is not a simple one for children to acquire. Their everyday experience reinforces their deeply held notion that the Earth is flat. More precisely, their mental model of the world separates `sky' and `earth' into two parallel layers, one `above' the other; the two directions `up' and `down' are absolute. Telling young children that the Earth is round does not cause their intuitive model to be replaced by a spherical conception of the Earth. Instead children assimilate the new information into their prior knowledge and often conclude that the earth is flat and circular.

The spherical Earth is a simple example of a deep idea ó a fundamental concept that lies underneath our extensive system of domain knowledge and influences how experience and discourse are conceptualized. Revising these deep ideas, these core concepts, is difficult because new knowledge is assimilated in terms of existing knowledge. When the new knowledge is both different from and more fundamental than the existing knowledge, the typical outcome is distortion.

The Round Earth Project is a collaboration among researchers in computer science, education and psychology investigating two alternative pedagogical strategies for teaching children that the Earth is spherical, and the implications of that fact. The transformationalist strategy attempts to effect conceptual change by evidencing a breakdown in the children's prior models. The alternative displacement strategy attempts to effect learning in an alternative setting free of pre-existing biases, and to relate that learning back to the target domain: the Earth. In the transformationalist approach, VR simulates the launching of a spacecraft from the Earth's (apparently flat) surface and subsequent exploration within a fixed-height orbit. In the displacement approach, VR simulates a small diameter asteroid where the learner may walk on a body with a curved horizon, see objects 'appear' from 'below' the horizon, take a long walk around the globe and come back to where they started.

The virtual worlds are collaborative. One child experiences the surface of the world as an astronaut and the other acting as mission control sees the avatar of the first child on the spherical world. The kids are given a task to perform so that the astronaut must move around the spherical body. This way the astronaut would often be 'upside down' on the sphere but 'right side up' on the surface. The task fosters positive interdependence as neither child can perform the task alone. They need to cooperate and communicate, and through this communication the children must reconcile their different views.

The children are first given a 5-minute orientation to each view showing them how to use the controls and also pointing out features of the environment which are important to the learning goal (the ability to circumnavigate the globe, seeing the tops of objects appear over the horizon first, not feeling 'upside down' when you are at the South Pole.) Each of the children then experiences each role for 10 minutes.

The displacement strategy then requires a second step. This new knowledge, established at the alternative cognitive starting point, must be brought into contact with the child's prior knowledge. The point is not just to know what it would be like to walk on a spherical planetary body, but to understand that the Earth is such a body. We call this second step bridging activities. This involves talking to the child about their VR experience for 10 minutes using a physical model of the Earth and the asteroid.

We have previously described our pilot studies that were conducted by bringing children to VR equipment in the laboratory [1,2]. For these actual studies we worked in close cooperation with the teachers and administration of a local elementary school. An ImmersaDesk driven by a Silicon Graphics desk-side Onyx and a stereo-capable monitor driven by a Silicon Graphics Octane were brought into a classroom in the school for two weeks, and studies on the displacement strategy were conducted on site. The ImmersaDesk was used for the astronaut view giving the user a wide field of view on the surface, while the stereo monitor was used for mission control. Figure 1 shows the setup in the classroom. Figure 2 shows a second grader as the astronaut at the ImmersaDesk and Figure 3 shows a second grader as mission control at the stereo monitor. Figure 4 shows the astronaut view and the mission control view as the astronaut approaches one of the crystal forests.

Figure 1: The ImmersaDesk and stereo monitor setup in the classroom

Figure 2: A guide introduces a 2nd grader to his
role as the astronaut at the ImmersaDesk

Figure 3: A guide introduces a 2nd grader to her
role as Mission control at the stereo monitor

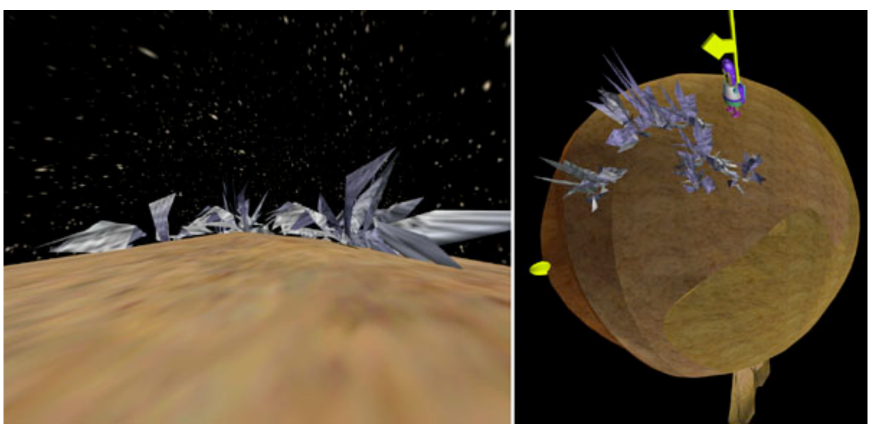

Figure 4: The astronaut approaches one of the crystal forests on
the asteroid. The left image shows the astronautís view while
the right image shows Mission Controlís view of the same event

There are 84 second graders in four classrooms at this school. 76 permission slips were returned (a pretty high return ratio) and all of these children took the 20-minute pretest. The pretest consisted of 18 questions spread over five topic areas: the sphericality and support of the Earth, the relativity of up, circumnavigation, occlusion, and egocentric Vs exocentric perspectives. These questions were asked three ways: verbally, with 2D paper drawings, and using 3D PlayDoh models. This was done to minimize representational bias. We developed a simple scoring system and divided the children into three groups: the high group answered 14 or more correctly, the intermediate group answered 11-13 correctly and the low group answered 10 or fewer correctly.

The 29 children in the low group were chosen as the treatment group for the VR experience. From our previous experiments with third grade children at another school, we expected to have a larger subject population. Because we only had fourteen pairs of children we had them all experience the displacement-based asteroid world. One week later randomly chosen pairs of these children went through the 30-minute VR experience and the 10-minute bridging activities. They were given the post-test on the next day.

During development we were concerned whether we would be able to create a compelling alternate reality. This did not seem to be a problem as several of the children reported being scared when they first stepped onto the asteroid in front of the ImmersaDesk, thinking that they would fall off the nearby horizon. One of the children was unable to continue as the astronaut. Another child reported being dizzy at mission control, but wanted to continue. Overall the children had little difficulty using the apparatus, but the adult guides who handled the orientation session stayed with the children during the VR experience to provide guidance.

As with our previous studies, the children became very focused on completing their task before their time ran out. Because of this, we waited until after the orientation phase to give them their mission. In the case of the asteroid, the two children are told that their spaceship has crashed on this asteroid and they need to recover fuel cells scattered about the surface to allow their spaceship to leave. Once they had their mission the childrenís dialogue tended to focus on getting to the next fuel cell. Mission Control would frequently tell the astronaut to 'go up' or 'go down' with reference to the sphere, which then initiated a conversation as the astronaut tried to map this direction into moving forward, turning left, or turning right on the surface.

The 22 children in the intermediate group became the quasi-control group. These children were given the post-test without having the intervening VR experience. To be fair, once these post-tests were performed the children in the intermediate and high groups were given a chance to experience the VR worlds.

The score for the treatment group increased from a mean of 7.3 correct out of 18 to 12.9 out of 18, and this change was statistically significant. The questions on the posttest were identical to those on the pretest so there is the possibility that the test itself contributed to learning. The quasi-control group, who didn't have the VR experience, saw their scores increase from a mean of 12.2 on the pretest to 14.0 on the posttest, and this change was also statistically significant, but the magnitude was considerably smaller. Additionally, the difference between the treatment group and the quasi-control group was statistically significant on the pretest, but there was no significant difference between the two groups on the posttest. This suggests that the combination of the VR experience and bridging activities brought the treatment group up to the level of their classmates in the quasi-control group.

Compared to our previous studies in the laboratory, this study in the classroom went much faster and required fewer personnel. Our previous experience with taking ImmersaDesks to conferences made the deployment to the school quite straightforward, and the 15-year relationship one of the investigators had with this school provided an environment of trust which was invaluable.

This study also showed that the children learned more than in our pilot studies, which we believe is the direct result of the changes made during those pilot studies. For this study we were able to use the adult guides more effectively at the beginning of the experience to point out features of the environment that were important to the learning goal. We believe that this orientation helped the students bridge the gap between the two representations of the astronaut on the asteroid, making it easier for them relate the two heterogeneous perspectives. We also modified our tests to ask the same question three different ways to avoid the biases that the media introduced into the questions and get a better idea of the child's model.

The children seemed very excited by the experience and as word spread through the school many children and teachers from other grades came by to see what we was going on. We were concerned that the children might be jaded by their familiarity with video games, but several children favorably compared our setup to a Sony Playstation. There was great interest among the children, teachers, and staff in having us return to the school for future work, and we plan to return in the late spring to continue this investigation. This will include giving a delayed post-test for the children that participated in this experiment, comparing the transformationalist to the displacement approach used here, and investigating the relative influence of the VR experience and the bridging activities.

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