First-Person Science Inquiry ‘in the Field’

T. Moher, A. Johnson, Y. Cho, Y. Lin

Electronic Visualization Laboratory
University of Illinois at Chicago
Chicago, IL, 60607

Abstract: In this paper we describe a class of restricted simulations, virtual ambients, designed to support science inquiry learning among elementary school students. These simulations employ large multi-user VR displays to support ‘first-person’ collaborative exploration, data collection, and the construction of support for hypotheses in simulated environments. In order to reduce the cognitive load on learners, navigation is used instead of the traditional learning simulations' direct control of independent model variables. Users may observe phenomena in virtual environments, but cannot affect the course of the underlying simulation. We report on our early experience with second, fourth, and sixth grade students in an elementary school employing a configurable virtual ambient named ‘the Field.’

1. Virtual Ambients

Elementary school science is about asking questions, collecting data that relate to those questions, and building support for answers [1, 10]. Throughout history, teachers have relied on accessible local environments to stimulate young learners' questions and to provide direct access to observable and measurable phenomena. Local environments have the advantages of convenience and salience, but they also have three important drawbacks: they may emphasize activity over learning [3], they may limit the domain of inquiry, and they may constrain teachers' ability to scaffold learning by reducing complexity.

For the past year we have been developing instructional interventions that employ ‘virtual ambients’ [9] as loci for children's scientific exploration. Virtual ambients are three-dimensional first person spaces within which users can navigate in space, scale, and time. Virtual ambients may include simulated scientific instrumentation, and may provide users with navigation and data collection aids. Virtual ambients may be static or dynamic, but unlike traditional simulations, virtual ambients offer users no direct control over independent variables. Nothing that the user may do within a virtual ambient can affect the course of the underlying simulation. This constraint is designed to reduce the cognitive burden of exploring complex input spaces [2, 5, 7] by limiting young learners to familiar concepts and activities: moving around, seeing things at different scales, and imagining the past and future. It does not preclude the articulation and investigation of causal hypotheses; it simply shifts the burden from artificially manipulating preconditions to finding instances of varying preconditions. This is not an uncommon model in science – astronomy has similar ‘limitations.’

Fig. 1. A view of the Field from the children's perspective, showing a cluster of eight different 'plants' and one of our most recent additions – a moving turtle.

Virtual ambients are implemented on large screen VR displays to support collaborative learning experiences for small groups. Because they are deployed on scarce resources, they are carefully constructed within a pedagogical framework that combines traditional whole class and small group activities with appropriate but less frequent technology-based work [8]. In the three pilot studies described below, learners spent about 30 minutes using virtual ambients, and about three hours in whole-class and small group discussions and activities. We believe that even these simple worlds can be the source of authentic learning experiences for young learners, and are consistent with emerging frameworks for technology-supported inquiry learning [4].

We also believe that the act of collecting and transcribing data will promote conceptual understanding by making the connection between the environment being studied and the 'scientific' representations of data drawn from that environment explicit. Evidence from other domains gives credence to this theory. Holst [6] for example, found that requiring the students to do manual data entry to algebra-learning software resulted in a significantly higher level of content mastery. Such evidence highlights the need to balance between scaffolding the experience and engaging in low-level activities associated with scientific investigation.

2. The Field

In the Field, shown Figure 1, students collaboratively explore a large 'natural' terrain containing up to eight different plant types. The Field itself has limited affordances: navigation, the ability to take 'snapshots', and the ability to plant an unlimited number of biodegradable marker flags in the ground. The land mass is a square 3000 feet on a side, divided into regions in two independent ways: picket fences divide the space into a 3x3 grid, and the different patches of terrain divide the ground into regions of grass, sand, and gravel.

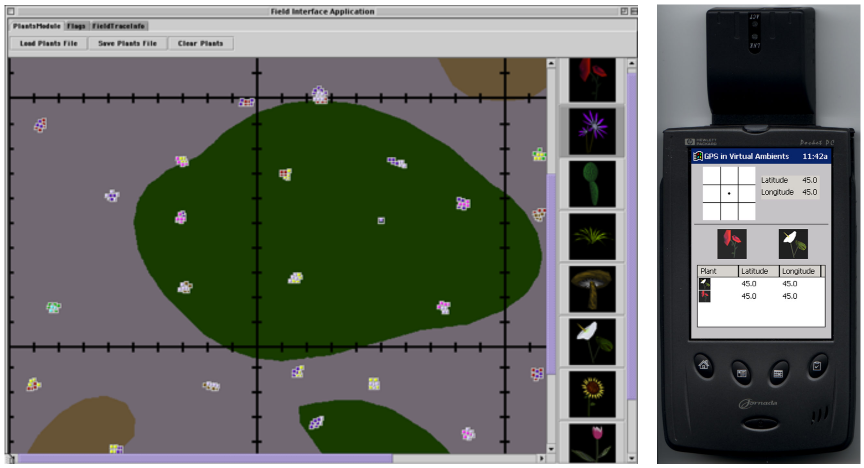

Fig. 2. The java client and the WinCE client. The java client is used to define the location of plants in the Field, as well as to monitor the users' movements and actions. The WinCE client can be carried by the children as a virtual instrument – a GPS receiver, a 'tricorder', or a note taking device, to collect data from the Field

The Field has been implemented on an ImmersaDesk® providing a wide visual field-of-view, and supporting collaborative investigations for up to four students comfortably. We are using an ImmersaDesk, driven by a 4-processor SGI deskside Onyx IR, that has been installed in the Media Center at Abraham Lincoln elementary school in Oak Park, Illinois since August 1999.

The Field has been written using YG, a scriptable language developed at EVL by Dave Pape that sits on top of SGI Performer and the CAVE library. CAVERNsoft is used for networking between multiple VR clients, and between the VR clients, the laptop-based Java client, and WinCE handheld devices. The Java client serves several purposes. Prior to the experience, it is used to set up the location of the plants in the environment. During the experience it allows us to monitor the position of the children in the space. After the experience it allows us to review their actions – the paths they took, the plants they marked, etc. This is a very useful ability, beyond what would be available in a real setting. See Figure 2.

So far 6th graders, 4th grades, and 2nd graders have had learning experiences in the Field. Jarvia Thomas' 2nd graders investigated issues of similarity and difference; Victor Baez' 4th graders learned about interpolation and extrapolation; Marilyn Rothstein's 6th graders learned to develop co-occurrence rules, and Joanna Peterson's 6th graders are currently learning to estimate population distributions.

3. Sixth Grade: Co-occurrence

Our first pilot study [9] was conducted in the spring of 1999. We configured the Field for a learning activity intended to introduce two classrooms of sixth grade students to the mathematical concept of co-occurrence. We distributed 400 plants over all nine sectors of the landscape in clusters of 6-10 plants, with each cluster containing two different types of plants.

Two groups of four students each acted as ‘scouts,’ making initial 20-minute forays into the Field. The scouting teams wrote general observations about the Field, and took digital ‘snapshots.’ The scouting team used the snapshots to make presentations to the class. Through the hour-long discussion, the class converged [11] on the task of determining the ‘plant buddies’ (the co-occurrence pairs). The teacher then discussed how they could ensure an accurate count within each sector; and how to ensure complete coverage. The scouts had reported that the individual sectors were too large to see across with the naked eye, and that the density of clusters was low. One girl suggested that the exploration teams could use a ‘lawn mower’ algorithm to ensure that the entire sector as traversed. Another girl raised the idea of using the flags to mark clusters that had already been counted. Because they suspected that the co-occurrence rules might be a function of terrain type, they decided to record, for each cluster, the two types of plants and the underlying terrain on which they were found.

The teacher organized the students into four-person teams and each team spent 30 minutes exploring their assigned sector. The students rotated through three assigned roles - navigator (made decisions on direction of travel), driver (controlled the wanda), data announcer (verbalized information about the path), and data recorder (transcribed announcer's comments and drew pictures). The use of small groups for exploration worked well; there was a great deal of interaction among team members, and their collective memories served well to recall strategies which individuals within the group had forgotten. The students said the rotation of responsibilities was ‘fair’ - an important consideration in an elementary school setting. See Figure 3.

Back in the classroom the individual groups aggregated their data. The final co-occurrence matrix contained only 44% of the clusters in the Field. Most of data points were lost during the exploration phase itself – partly though sloppy note-taking and partly due to their failure to follow a systematic traversal algorithm. Figure 4 shows the traversal path employed by one of the groups, which failed to explore several large regions of their assigned sector. Interestingly, when the teacher asked the students whether they believed that they had found all of the clusters in their assigned sector, all of the groups confidently reported that they had. The students were quite surprised when a checking group went back into the space and reported that a significant number of clusters had been missed. More data was lost during aggregation, principally due to a lack of common vocabulary – different groups came up with different names for the plants and it was difficult for the children to shift between these different names. All of this is not necessarily a bad thing – it was certainly a learning experience for the children to make these mistakes, and see the need for organizing this kind of survey up front. However it did seriously impact the original goal of studying correlations.

Fig. 3. A group of sixth graders exploring the Field on the ImmersaDesk

One change that we made during this first study involved head-tracking. Given that we had multiple students viewing the Field, and frequent changes of control, we decided to turn off head tracking. This allowed the students to change drivers by merely handing over the wanda rather than also needed to exchange the tracked glasses.

4. Second Grade: Similarity & Difference

The second grade students visited the field in spring 2000, focusing on similarity and difference. For this unit, only a single sector of the Field was employed, which was configured with 24 isolated plants - three each of the eight available types.

The activity began with a one-hour discussion between the teacher and the students. The teacher brought a collection of cut flowers of various types, colors, and sizes to the class. Holding up pairs of flowers, the teacher asked the children in what ways they were alike and different. The children articulated several important observations during the discussion, including the relationship between flower shapes and type, the fact that color alone might be insufficient to distinguish one type from another, and the fact that two plants of the same type might not be the same size.

The children were told about the Field, divided into eight groups of three students each, and given the task of determining how many different types of plants can be found there. They were to explore the space and come back together as a class to determine the unique plant types. Unlike the sixth grade unit, a complete survey was not expected; the children hypothesized that plants missed by one group would probably be found by another group. Because no 'scouting' activity was included, the students had no snapshots of the plants at the outset. They decided that they would need to make drawings and write brief descriptions of the plants that they found.

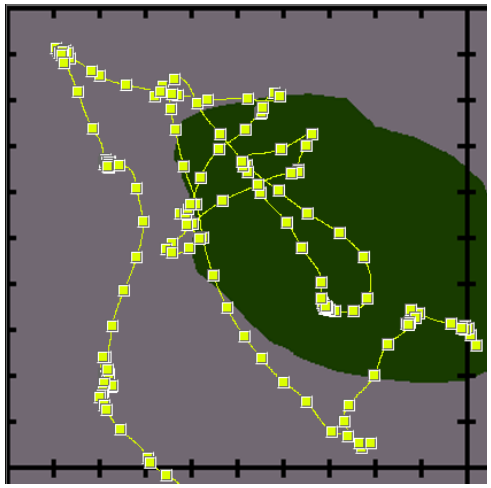

Fig. 4. Bird's eye view of the traversal pattern of one group. Instead of using a lawn-mower algorithm, the kids moved from cluster to cluster, leaving large areas of their sector unexplored.

The students were pulled out of class to participate in the exploration on the day after the discussion. Each team brought its own paper, crayons, pencils, and markers, and spent 30-45 minutes exploring. One child took the role of driver; the other two children were responsible for drawing and writing about the plants that the driver found. Again, the roles were rotated for fairness.

The next day the students sat on the floor of their classroom in their groups. Each group presented their drawing of a candidate 'new plant.' Since we knew which plants each team had found, we sequenced the groups to ensure that all the teams could introduce a new candidate. As each candidate was introduced, the class discussed whether it was really new, or simply a different picture of a plant that had already been presented. The students showed strong interest and group pride as they presented their candidate plants. In one instance, a group introduced a plant that had been previously put forward by another group. The class was evenly divided on the issue of whether the plant was new; it matched the earlier plant in colour, but differed in the number of leaves. This discrepancy led to two important discussions.

First, the teacher asked the class whether they it might be the same plant, just drawn from a different perspective. This was an interesting question as the students had paid little attention to obtaining multiple perspectives during their exploration. Typically, the students would happen upon a plant through relatively random navigation, walk up close, stop, and draw the picture. At no time did the students spontaneously articulate a strategy of walking around the plant in order to facilitate their drawing. An interesting question is whether the children would have spread out around the plant in the real world and made their drawings from several perspectives.

Second, the teacher noted that even scientists might offer different descriptions of the same phenomenon, and asked how scientists might go about resolving their differences of opinion. The class discussed - and rejected - the idea of voting to see which was correct, and articulated a strategy of sending a neutral observer back to check.

Once the class reached consensus on the set of unique plant types, each group was charged with producing an archival ('really good') drawing and description of the plant that they had introduced during the follow-up discussion. The final drawings were collected by the teacher, scanned, and combined into a montage.

The unit was well received by the children. There appeared to be little difference between the sixth and second graders with respect to use of the apparatus. The students worked well in their teams, and clearly benefited from the more detailed planning with respect to data collection tasks. They had a very clear conception of the overall process, and what was expected of them at each stage of the unit.

A major difference between the experiences of the sixth graders and second graders was the focus on tangible work products. Having the second graders to produce "archival" pictures and text greatly enriched the activity for them, and provided us with more material to characterize their learning experience.

Students were then asked to write brief answers to two questions: "What did you do?" and "What did you learn about what scientists do?" We classified each phrase in their responses to the first question into several categories based on what they referenced:

- social interaction ("Me and Jimmy went up to the media center...")
- the technology apparatus ("I put on the glasses...")
- exploration ("First we went along the fence for a while...")
- data collection ("The plant had three green petals...")

We had expected that the descriptions would emphasize the novel apparatus; we were surprised to find that it accounted for only 14% of the students' responses. Descriptions of exploration and data collection accounted for 30% of their comments, with the remaining 56% describing their interactions with their peers. To the second question, a majority of students articulated the need to "go back and look" when scientists disagree. Their responses suggest that the students truly became engaged in "doing what scientists do." For the second graders, the Field was a real place, populated by real things, where they did real work.

5. Fourth Grade: Interpolation & Extrapolation

A classroom of fourth grade students visited the Field in fall 2000, focusing on interpolation and extrapolation. Only a single sector, and only a single species of 'plant', the mushrooms, were employed. The students investigated the differential growth rates of the mushrooms based on the soil type (grass, sand, rock) and tried to predict how many mushrooms would grow by the end of the season. This was important to the students because mushrooms are the favourite cuisine of the Snookerpuss – a mysterious creature that hibernates during the summer and wakes in the fall. The students needed to find out if there would be enough mushrooms available when the Snookerpuss awoke so it wouldn't need to find other food, such as 4th graders.

The class was broken up into teams where each team visited the field in a different virtual month (June, July, etc) and counted the number of mushrooms growing on each soil type. Within two days at school, the different groups explored the same sector over eight months of growing time.

Afterwards the children collated their data and plotted the growth rates of the mushrooms on three graphs (growth in rocky soil, sandy soil, and grassy soil) as a classroom. After introducing a ‘best-fit’ line, they predicted of the number of mushrooms that would be available at the end of the Snookerpuss’ hibernation. They confirmed their favorable prediction by sneaking into the field in October just before the hungry Snookerpuss awoke. From the graphs they also concluded that the mushrooms grew most rapidly in the grass, and recommended that next year the mushroom spores be distributed in grassy areas to maximize the yield.

In follow-up activities, the children described their surveying strategies, and developed new predictions based on hypothetical data. Although the children had not previously been introduced to linear prediction, 75% of the class was able to construct a supported prediction. The next month, when the kids were formally introduced to the concepts of linear interpolation and extrapolation, they repeatedly cited the Snookerpuss adventure.

Each child spent roughly 30 minutes using the display technology, and two hours in small group and whole-class activities. The Snookerpuss adventure accomplished two complementary learning goals. It helped the children develop their understanding of transforming between numeric and graphical representations of data, linear best-fit, interpolation, and extrapolation. In the discussion comparing the relative growth rates in different terrains, the kids even touched on issues of steepness and slope. It also helped develop skills for conducting scientific inquiry, including planning investigations, navigational strategies within a survey space, observation of phenomena and recording of data, distribution of effort within an investigational team, reporting of their results, and the aggregation of data across teams in a large-scale project.

6. Beyond the Field

The Field is the simplest kind of virtual ambient; offering a static model of an environment where users can navigate and make visual observations. We are currently enhancing the virtual ambients in several ways.

- The current field already sends data to the java application so we can track the position of the children in the space. We are also sending the data to a WinCE hand-held where we create virtual instrumentation. Adding simulated instrumentation to virtual ambients allows the study of both instantaneous and cumulative phenomena.

- It is important to extend the domain of phenomena beyond those readily accessible to learners. Fields of plants are not hard to access, the surface of Mars is.

- Nature moves and grows, and understanding dynamic phenomena is an important part of the scientific enterprise. As part of a unit on sampling and population distributions, we have created some turtles that will slowly move around the field so the children can explore differential strategies for population estimation.

Ultimately, the real question is whether science inquiry skills acquired in a virtual environment can be effectively transferred to real world situations. We will explicitly investigate this in the next school year.

We see two major barriers to sustaining the virtual ambients approach. First, the technology is far too expensive. Second, moving children to another room for the VR experience creates difficult learning and management problems for teachers, and requires the availability of additional personnel.

Fig. 5. Two new displays we are going to try out in the school in the next year – a passive projection screen, and a 50" plasma display, both driven by Linux PCs

We are exploring alternative delivery strategies to address these problems. YG, Performer, the CAVE Library, and CAVERNsoft work under Linux as well as IRIX, so we have ported the Field to an SGI Linux PC using a 50" diagonal plasma panel. In April 2001 we will deploy this system. We lose stereo visuals, but will maintain hand-tracking for the virtual instrumentation and the large screen allows us to continue supporting small group interaction around a shared display. A second option uses a Linux PC with a GeForce 2 MX card driving two stacked DLP projectors to project a passive stereo image. This option would use more space in a classroom, but gives us back stereo visuals. Both of these technologies represent an order-of-magnitude reduction in cost compared to our current setup, and employ consumer-driven commodity technologies with steep performance / price slopes. See Figure 5.

We envision a system that provides access to a virtual ambient for an extended period on a 'walk up and use' basis, like an ant farm, or other phenomonenaria in classrooms. As contemporary elementary school classrooms are increasingly organized around small-group activity centers, this organization allows the teacher to opportunistically provide access to the virtual ambients during regular daily activities.

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