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An Ethnographic Comparison of Real and Virtual Reality Field Trips to Trillium Trail: The Salamander Find as a Salient Event

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Abstract
Reported are ethnographic observations comparing and contrasting real and virtual reality field trips. The content was from a fourth grade elementary science and ecology curriculum of the Audubon Society of Western Pennsylvania. Ecology education is an area of enormous importance, especially now in the period of climate change. Technology may help to disseminate crucial knowledge and understanding required for appreciation and respect of natural places, both near and far. The system developed is unique, as it is a high-fidelity, data-based ecologically accurate simulation of the real field trip. The study used a counterbalanced design, (Real-Virtual and Virtual-Real groups), which made a post-experience survey meaningful. After both experiences students rated the Real superior to the Virtual in Learning, Inquiry and Presence. However, after the First experience, Real or Virtual, a posttest showed no statistical difference between experiences. Our claim is that both results are true. Additionally, observations suggest that the two environments complement. Many of the out-of-curriculum learning events only occurred in the real environment as unplanned surprises resulting from nature. One such "salient event" was the sighting of a salamander, which allowed the dynamic and sensitive naturalist guide to relate the unplanned event back to the curriculum for maximum impact on long-term episodic memory, thus documenting the effectiveness of "the teachable moment," and the environment-guide-child interaction dynamic. This paper offers insights for both educators and software designers.

Keywords: ethnographic, discovery-based learning, intrinsic motivation, human-computer interaction, elementary science and ecology education, real and virtual reality field trips or simulations

Introduction

The aim of this report is to document, compare and contrast two learning environments, one "real" and one "virtual." Clearly the real offers more opportunities for learning, is multi-modal and authentic, but the virtual can offer learning experiences in places that are not accessible for normal school field trips, such as the rain forest, the Artic or the Great Barrier Reef. The aim of the paper is not to build an argument that the virtual should replace the real, but to learn more about the two learning contexts and activities and to compare and contrast the two environments in a carefully designed study. There is a strong possibility for détente between real and virtual, where one environment complements the other for a far stronger overall learning experience.

This study involved two groups of fourth-grade students experiencing both a real and a virtual reality version of the same field trip. The ethnographic observations reported here[1] involved video- and audiotape recordings, photographs, and field notes of the teacher and student activity in both the real and virtual field trip environments. The videos documented the students' activities, behaviors, inquiries, questions, and personal responses to new knowledge. Each experience was limited to one-and-a-half hours, with the same guide for both. The guide was a trained naturalist and educational expert from the Audubon Society of Western Pennsylvania. There were six students in each group (*Real-Virtual* and *Virtual-Real*), for a total of twelve students. The two groups allowed all students to experience both the real and the virtual field trips, but in opposite order. The real field trip was to the Trillium Trail Wildflower Reserve, located outside Pittsburgh, Pennsylvania. The virtual field trip took place from a computer lab-classroom in the School of Information Science at the University of Pittsburgh. Each child had access to his / her own computer, and could interact with the guide and each other at will.

This paper presents ethnographic observations from the real and the virtual field trips as examples of discovery-based learning activity and outcomes. The main focus of this report is the documentation of teacher-to-student relationships, student-to-environment relationships, and the tools used to facilitate children's intrinsic desire to know. Looking from a different direction entirely, the study also demonstrated that high-fidelity video games can offer real-time interaction with full freedom of movement that can simulate reality with a high degree of validity, and are thus a low cost option for scientific simulations. This type of platform goes beyond traditional multi-media, as it offers full freedom of movement. This study leveraged the game engine from Unreal Technologies (Unreal Technologies 2008). The technical interest in the project was to construct a baseline study to enable future work.

[1] The analysis reported here is part of a larger study which investigated ethnographic, empirical in-situ learning activity, post activity affective and emotional reactions, and creative microworld follow-up activities. The analysis reported here has not been reported elsewhere.

Theoretical Background

Most children from developed countries experience school science and ecology education in the classroom. The science curriculum may include units on nature and ecology, biology, chemistry and physics. Books, lectures, in-class or in-lab activities are the methods used to present materials. However, science, and especially ecology, is part of the natural environment and is constantly occurring in places all over the world and in every community—urban, suburban, rural, or wild.

On certain occasions, field trips to local places of interest, such as to a local nature reserve with an expert in the subject area, provide meaningful experiences and ways to interact with and explore nature and ecology information in context. This context is spatial, temporal, multi-dimensional, multi-signal, multi-modal, and multi-faceted. On site, the children can see, hear, feel, smell, and even taste items under investigation. In terms of the theory of "multiple intelligences" (Gardner 1983), this type of multi-sensory experience is powerful, as it provides many kinds of signals varying in importance for each type of intelligence. Integrating data, information, and knowledge from the experience can leave a lasting and meaningful impression, resulting in deep conceptual change for the child. Based on the higher signal salience and redundancy gains provided by the natural world, powerful learning results are expected from real field trips.

Sometimes, an unexpected find makes the experience memorable: a turkey hen on her nest, a doe and her fawn bolting, a great blue heron in flight, a pileated woodpecker hammering, a water snake swimming. This surprise event, if properly seized by the teacher, becomes a "teachable moment" (Bentley 1995). Episodic memory is more accurate and more stable over longer periods. Field trips provide opportunities for this type of learning activity and may thus provide a long-term, correct, stable knowledge structure for scientific understanding. The salient factors are investigated and students are expected to develop a deeper understanding of these factors.

If a community is fortunate enough to have school science programs that incorporate natural and local resources into the curriculum, those experiences can become personally meaningful to students. These events can become powerful learning experiences, part of the children's information and ecological knowledge base. A science lesson in the field can empower a child to know more about the plants, animals, and interacting dynamics found, for instance, in their local parks. These "backyards" then become rich in information, to be shared with friends and family afterward; moreover, they may provide important access points for the creation and development of "islands of expertise" (Crowley and Jacobs 2002), particularly in science. The environmental factors that cause an increase in curiosity, exploration, and knowing are of investigative concern. Additionally, understanding and modeling how these factors dynamically interact to cause a holistic understanding of the environment is a goal.

Personalization is often also used to advantage in Human-computer interaction (HCI) to improve the student-computer interface with adaptive intelligent tutoring systems and user-modeling which facilitate personalization (Brusilovsky 2002).

Simply, if the children are curious about it, they get to learn about it. As the virtual field trip allows complete freedom of intellectual and navigational movement, the virtual condition should show advantages over the real in personal exploration and discovery.

This intrinsic desire to know is part play (Papert 1993 and Resnick 2004) and part flow (Csikszentmihalyi 1991), and is critical because a key assumption of this research is that self-motivation and free will are at the heart of knowledge-seeking behavior, new ways of seeing the world, and creativity. This real-time, dynamic, individual inquiry supports the child's intrinsic desire to know and supports independent exploration in a meaningful and salient way. However, motivational factors for the intrinsic learner are largely unknown. The expectation is that the post-experience attitudinal survey will be invaluable in attempting to understand intrinsic motivation.

Technology has been used to create virtual reality learning environments in the past. Youngblut (1998) surveyed virtual reality for use in education. The early research was exploratory (Wickens 1992; Winn 1993; Dede 1995), and much was set within the framework of scientific inquiry (Jackson and Fagan 2000; Johnson et al. 1999). Recently, researchers have investigated the role of social collaboration (Barab et al. 2007; Dede et al. 2005; Roussou et al. 1997). Others have approached the problem from a perspective of human factors (Salzman et al. 1998). The results have shown that in virtual environments, learning in terms of knowledge gained can occur, as measured by a pretest and a posttest on facts and concepts. For example, the MaxwellWorld results of Project Science Space showed gains of close to 20 percent (Dede et al. 1999; Salzman, Dede, and Loftin 1996). Similarly, the Multi-User Virtual Environment (MUVE) showed measurements of knowledge gained of close to 35 percent (Dede et al. 2005), indicating the advantages of a socially engaging environment. Moreover, the high-fidelity simulation of the Virtual Environments in Biology Teaching project showed knowledge gains of close to 50 percent (Mikropoulos et al. 2003), indicating that reality, really does matter. Thus, the expectation is that learning will be possible in the virtual condition and that it will be possible in this study to compare and contrast it with the real condition with a high degree of internal validity.

Population and Sample

Study Population

A volunteer sample of students (*N* = 12) from a local suburban public elementary school located outside Pittsburgh, Pennsylvania participated in the study. Ten were in fourth grade, one was in third grade and one was in fifth grade. There were eight girls and four boys. They ranged in age from 9 years old to 11 years old. The school district's population is diverse but biased towards an upper socioeconomic profile. The school from which the volunteers were drawn is a high-achieving Blue Ribbon School, with its Grade 4 District Report Card noted as "proficient and above." The PSSA test scores, as reported for the school district, were 93rd percentile in math and 86th percentile in reading (Pennsylvania Department of Education 2002). At the school, class sizes range from 18 to 24 students per teacher. It has a very active parent-teacher organization, with high parental volunteer involvement (10 percent and almost a 1:1 parent-teacher ratio) and highly respected teachers with virtually no turnover. The school offers computer classes for all students, white-board technology, and a wide variety of computer technology integrated into the classrooms. To enrich science and ecology lessons, the students and school have access to local parks with integrated Audubon Society-directed field trips at all grade levels. All students have participated in various real field trips to many of the local parks and nature reserves with the naturalists and parent volunteers throughout their elementary school experience. The sample was one of convenience, but it also offered an ideal baseline from which to start a long term design process. Future work will extend into different populations, such as inner-city and rural communities.

Pilot Study Sample

A pre-experience user profile was gathered for all student volunteers. The sample reported expert levels on the measures of "Computer Skill" (100 percent owned PCs, M = 8.5, Median rank = 10/10), "Video Gaming" (75 percent owned video games, and 100 percent had used video games), and "Enjoyment of Nature" (100 percent had been to Trillium Trail, M = 8.5, Median rank = 10/10). Thus, the "Computer Knowledge" and "Enjoyment of Nature" descriptives between the groups are identical and high. A t-test for "Computer Knowledge" shows no difference between the user profile results: $t(10) = 0.00$, $p = 1.00$, two-tailed. A Mann-Whitney U-Test, as a more appropriate statistic for such ordinal data, shows U = 16, N=6, $p = 0.818$, two-tailed. A t-test for "Enjoyment of Nature" shows no difference between the test results: $t(10) = 0.143$, $p = 0.889$, two-tailed. A Mann-Whitney U-Test shows U = 15.5, N=6, $p = 0.70$, two-tailed. The descriptive, parametric, and nonparametric statistics indicate that there are no observed differences between the two groups in terms of "Computer Skill" and "Enjoyment of Nature." Thus, the hard claim is that these two dimensions of investigative concern between the two groups are identical.

$$H_0: M \text{ Pre-experience Profile}_{\text{(Real-Virtual)}} = M \text{ Pre-experience Profile}_{\text{(Virtual-Real)}}$$

Random sampling from the population is impossible due to U.S. Federal Regulations that protect human subjects in research, and random assignment was impossible due to the practical constraint of working with children and very busy families. All 12 students were from the same elementary school, and ten of the 12 students were from the same class with an expert science teacher, and thus the soft claim that the students had very similar pre-experience knowledge is made. A pretest was not possible in this situation and so the hard definitive claim can not be made; however the students were exposed to the same curriculum from September to May in preparation for the field trips and so they had the same background and training. Thus, the homogeneous user-profile sample was established. Furthermore, for the purpose of software design and development, this user profile was ideal. If an experimental system cannot perform adequately under ideal conditions, it certainly could not under challenging conditions.

Materials

The Real Trillium Trail

Trillium Trail is a wildflower reserve located in Fox Chapel, Pennsylvania and the location for the real field trip. Here, children experience nature and learn in the open classroom through a nationally recognized ecology educational program. The program's original vision was first implemented by Ruth Scott and Ruth Boyles in 1968, and directed by Beulah Frey (Stehle 1988). The Beechwood Farms Outdoor Discovery Hike philosophy (Beechwood Farms Nature Reserve 2005) is based on "teachable moments" (Bentley 1995). It works with guide-facilitated, but child-initiated inquiry. The guide is flexible and adapts to the various finds along the way. These events can be anything, and do not have to be in the original curriculum. The educational experience is highly personalized, open and customized to the learner's existing knowledge, desire to learn and the environment. Thus, the real-world interaction is highly personal and situational.

The Virtual Trillium Trail

The Virtual Trillium Trail is a computer simulation of the real Trillium Trail and the real field trip materials (Figure 1), implemented in a common video game engine. The simulation provides a near-realistic experience for the user representative of the highest level of development at this time. In the simulation, the child can explore, navigate, and learn. As such, it is personal, situational, and contextual. It has events, is multi-modal in two dimensions with visual and sound effects, and is completely under the student's navigational control. The sparse user interface implemented for this study consisted of a virtual fact card positioned next to each plant of interest. The fact card had a photograph, a schematic drawing, and descriptive plant facts. The students used the arrow keys on the PC keyboard to move forward, backward, and sideward, and the mouse to pan and position in front of the card targeted to read. They could select the Ctrl-F key to switch to "fly mode" and the Ctrl-W key to enter the "walk mode."

The system was designed and constructed between 2003 and 2008 with a video game software development toolkit, Unreal (Unreal Technologies 2008), and other third-party computer graphic tools. The model visualizes approximately one square mile of local ecology terrain contour data (30mm Digital Elevation Model format) and locally gathered textures from over 1,500 on-site photographs. The ecological regions visualized are based on over ten years' worth of scientific biological plot study data (Kalisz 1996-2006). The simulation is populated with semi-automatically created 3D computer graphic objects of indigenous plants (4,000 objects of 500-1500 polygons each), landmark formations, and water, producing a model that totals to approximately 10 million polygons. The application runs on a Dell XPS Gen 2 with a NVIDIA high-end graphics card. Currently, there are 36 plant species modeled out of the 102 real plant species in the park. The simulation is representative of the ecological environment as it would exist in early May, and as it would appear without any human development or excessive deer populations. Every attempt was made to accurately simulate the real field trip. The Virtual Trillium Trail is unique for learning as it is built in a high-fidelity, 3D computer graphics game engine and also simulates a real place and a real curriculum.

Figure 1. The Virtual Trillium Trail, a high-fidelity simulation for learning first prototype

Educational Curriculum

The educational content embodied in the system was based on the Audubon Society of Western Pennsylvania's "Natural Communities" curriculum for the fourth grade (Beechwood Farms Nature Reserve 2005). The Audubon managed programs augment local public schools academic curriculum. With the help of a fourth-grade public school teacher and science expert, the researcher compared the school's science curriculum to the Audubon content, and it was determined that the school's curriculum was a sub-set of the Audubon's curriculum. Further analysis was conducted with respect to the Commonwealth of Pennsylvania Ecology standards (Pennsylvania Department of Education 2002), and it was concluded that the state standards were a subset of the school's curriculum.

The teacher's expectations of the real field trip included: 1) the students would learn two new plants and increased observational sensitivity to the parts of the plants, adaptations, and salient features; and 2) they would gain a deeper understanding of watersheds and forest communities, 3) biotic and abiotic interactions, 4) Northeastern forests and the layers of the forest, 5) pollination in action, 6) photosynthesis in action, and 7) deeper understanding of the web of life, ecosystems, and the interconnecting dynamics found on site. We determined that the virtual field trip was adequate to support the content for teaching such material.

Research Design and Procedure

Design

This study design compared and contrasted the students' experiences of the two environments through a detailed ethnographic analysis, complemented by additional data (Figure 2). The research aim was not to prove or disprove formal hypotheses, although they are stated for clarity, but instead to holistically and accurately capture the critical events, actors, and reactions. There are teaching and learning practices as well as software design features and functions to be distilled from this ethnographic analysis. Future research may use this ethnographic report to generate new hypotheses.

Figure 2. Study design (*N* = 12)

Group	First Experience		Second Experience	Post-Experience Subjective Evaluation
Real-Virtual Group (*N*=6)	***Real Experience*** - Video Documentary	Posttest	***Virtual Experience*** - Video Documentary	- Interview & Survey
Virtual-Real Group (*N*=6)	***Virtual Experience*** - Video Documentary	Posttest	***Real Experience*** - Video Documentary	- Interview & Survey

Posttest on Educational Facts

In addition to the ethnographic report, after the students had their first field trip experience, whether virtual or real, they were administered an empirical posttest of in-curriculum facts to assess the learning impact of each experience. Thus, one group completed the post-test after the real field trip, and the other group completed it after the virtual field trip. Both groups received the same test. The hypotheses for the post-test were:

H_0: *M Real* Posttest Score = *M Virtual* Posttest Score
H_1: *M Real* Posttest Score ≠ *M Virtual* Posttest Score

The posttest was a 15-question test derived from the Audubon Society's "Natural Communities" curriculum. Additionally, a fourth-grade teacher who was a science content expert reviewed the test prior to its use in order to help refine and improve it, as well as to help determine pre-experience curriculum exposure. The rationale was to co-design the test to avoid floor or ceiling effects, priming effects, and the time and cost of a pretest. For example, the teacher identified that prior to the field trip, the students had been taught about watersheds and the formation of valleys, habitats, photosynthesis, and pollination. Also, based on five years of teaching experience including the field trips, the teacher established that the after the Trillium Trail field trip, students should be expected to know the names of at least two flowers but no tree or bush names. Questions on the posttest examined that knowledge, as well as facts and concepts related to plant adaptation, forest canopy, forest community, and biotic and abiotic interconnections. Also, the test asked a question about dynamic interactions of natural form and function, which were emphasized on the field trip but not covered in depth beforehand.

Test activities included fill-in-the-blank and connecting lines from text to parts of drawings, as well as open-ended essays and a drawing activity. Specifically, the posttest asked each child to name as many trees, bushes, and plants as they knew in the local parks. To capture both their knowledge and personal value of forest ecologies and dynamics, they were requested to write a story and draw a picture of a park, forest, or flower. Finally, they were asked to describe why such places are valuable.

Post-Experience Comparison

Both groups of students experienced both the real and virtual field trips, but at different times and in different sequential order. In order to compare their impressions and perceptions, after the completion of both field trip experiences, the students' subjective emotional, affective, and attitudinal responses were explored through a post-experience interview and survey. This posttest study used repeated measures, within-subjects, counterbalanced design. In such a design, there is no need for separate control groups, as each subject acts as his / her own control, counterbalancing the order in such treatments as are assigned (Siegel 1956, 62). Specifically, the interview consisted of 12 open-ended questions and the survey had 14 closed questions answered with a five-point Likert scale (see Appendix). Each question was asked about each field trip experience, real and virtual, so there are two results sets per student, allowing an accurate comparison between their real and virtual experiences.

H_0: *M* *Real* Attitudes = *M* *Virtual* Attitudes
H_1: *M* *Real* Attitudes ≠ *M* *Virtual* Attitudes

Procedure
The experiment required three weekends in early May 2007, when the real flowers were in full bloom. As seen in Figure 3, below, the activity in the two conditions was very similar; key differences are noted in bold text.

Figure 3. Comparison of the real and the virtual sequence of events

Real Field Trip	Virtual Field Trip
1) Natural Communities Curriculum	1) Natural Communities Curriculum
2) Six children in group	2) Six children in group
3) With peers	3) With peers
4) Expert Guide – Audubon	4) Expert Guide – Audubon
5) Parents – each child's	5) Parents – each child's
6) Tools: a. wildflower field guide reference book b. map	6) Tools: a. wildflower field guide reference book b. map
7) Augmentation: a. note cards on the trail next to plant i. schematic drawings ii. facts	7) Augmentation: a. virtual note cards on the virtual trail next to virtual plants i. schematic drawings ii. facts
8) There is a path to follow	8) There is a virtual path to follow
9) Child **may not go off the path**	9) Child **may go off the path**
10) Child **may not explore at will**	10) Child **may explore at will: (e.g., fly, jump off cliffs, travel through the tree canopy and play in water**)
11) Guide points out plants, animals and insects of interest along the way—passive learning, but it also triggers questions. The guide may point out items of interest in context.	11) Real guide (same guide from the real field trip—not an avatar), will not point out animals or insects, but points out plants of interest along the way—passive learning, but it also triggers questions. The guide may point out items of interest in context.
12) **Guide answers child-initiated questions at the time of inquiry and to the depth desired.**	12) **Guide and the user interface will respond and allow the child to inquire at will.**
13) **Surprise animals** in the environment or unexpected finds provide unexpected and abrupt changes to the lesson flow.	13) **No surprise animals** in this prototype.

All student volunteers completed a demographic survey prior to their first field trip experience. Each student was given a unique number, personal map, and wildflower field guide book (Thieret, Niering and Olmstead 2001). They were instructed to annotate their map for items of personal interest, to use their field guide books to look up information of interest, and to listen and ask questions. The students knew that plants had note-cards next to them with facts; finding the cards became at times a self-directed goal but it was not an explicit instruction. After the first field trip, we collected all student maps and recorded their annotated data. Then, as mentioned above, all students were given a posttest on the facts and concepts. On the second field trip, whether real or virtual, we returned the students' maps to them. Again, after the second field trip, the maps were collected, annotations recorded, and an attitudinal interview and survey were administered.

Research Results

Ethnographic Observations of the Real Field Trip

The real field trip to Trillium Trial Wildflower Reserve (Figure 4) was guide-facilitated by an expert naturalist who has extensive experience in conducting these educational activities, and who was familiar to and much-adored by the children.

This was their fourth year taking such trips, so the students understood the expected behavior. As on a typical field trip to Trillium Trail, children carried their journal, field guides, and maps, and walked along one of the many foot trails in the reserve, usually walking in a line or clustered in pairs. The children followed the guide along the trail or the stream, and the guide controlled the group's pace and direction. They were in the same place at the same time and mostly perceptually and cognitively unified. Even when some children walked ahead, they stopped to call back to the guide and the group upon discovering interesting finds.

Factual note cards had been placed next to plants along the trail, as surprise finds and potential objects of discussion. They often stopped to inquire about plants that had a note card next to them, either naming plants they knew or asking questions about them. Sometimes, the guide saw items of interest that the children did not notice, and drew their attention to them, often asking if anyone knew what the objects were. Each time, she ensured that a different child participated. She was particularly attentive to students who were not engaged and tried to connect to them. The guide encouraged the children to observe, touch, smell, and listen to their environment.

Non-planned items of interest, such as dead logs, rocks, animal tracks, pellets, and nests, were also in the environment and facilitated discussion. There were moments of true salient surprise in the environment such as a bird, deer or frog that would suddenly appear. The knowledgeable and skilled guide integrated these unplanned salient events into the discussion effortlessly as a "teachable moment" (Bentley 1995). The guide continuously related the finds to the educational curriculum, the forest, the watersheds, the interaction of the abiotic and biotic forces, or how to identify the found plant or animal. The students learning activity was one of constant integration and organization of the new information.

Figure 4. Photographs from the real field trip at Trillium Trial in May 2007

The guide told stories about the topography, geography and ecology of the nature reserve, relating form and function to abiotic and biotic interactions. She wove concepts of watersheds, forest communities, and natural cycles into the stories, as well as niches, life cycles, food-webs, photosynthesis, pollination and symbiotic relationships of life in the forest. In this use of storytelling, she connected the land, plants, and animals with the immediate context and experience.

The experienced guide integrated context, experience, observation, senses, emotion, and social factors into the lessons. For example, the guide picked a sample of a plant called Cleaver, commonly referred to as bed-straw, and placed it on a child's shirt, where it stuck. She then instructed the children to pick a small sample and place it on each other, which led to much delight and giggling as the children got to participate. The guide then encouraged them to think about the reasons why the plant could stick—it had Velcro-like barbs—and the reasons for such an adaptation. It was this plant's adaptation that allowed the plant's seeds to attach to animals and thus to use the animals for seed transport. The group discussed other plant adaptations used for seed transport, such as dandelions' use of wind-born seeds.

The children's olfactory senses were easily incorporated into the lessons with the smells of the many flowers found locally. Some plants were sweet-smelling, some repulsive, and others bitter. The students sampled each scent and discussed its reason for being, such as to attract insects for pollination or to repel an herbivore. When serendipitously found, the guide discussed other interesting plant-pollination strategies, such as the use of violet (ultraviolet) colored lines on petals to show insects where to find the flower's nectar and thus the pollen.

Similarly, the use of taste was carefully introduced and used to help create a lasting impression. For example, students were encouraged to pick, crush, and taste a small sample of an invasive species called garlic mustard. Many students were intensely interested in which plants they could eat. (Nonetheless, all children were strongly discouraged from harvesting wild plants on their own, due to the danger of poisonous plants found locally.)

The following example from the research notes is representative of the way the guide led the children through the educational lessons found in the nature reserve on the real field trip. Group 0 was the code for the *Real-Virtual* group order, and each student is identified only by number.

> Guide: *OK, does anyone know what this plant is?*
>
> Group 0: *Umbrella Plant, Mayapple, Mayflower, Mandrake…*
>
> Guide: *Wow, all of you are so smart, this plant is known by all of those names. Look around, notice we are low in the valley, we are on the north side of the range, more shady than the south side* [she points across to the south-facing slope]. *This plant likes the moist, nutrient-rich, soil down here by the stream in the herb layer of the forest* [she points down and crouches close to the ground]. *The plant likes the cool wet areas. Can anyone tell me what is so special about this plant?*

S7: *It is used to cure cancer?*

S9: *It is my favorite, it is so pretty!*

S10: *Doesn't the turtle eat its fruit?*

Guide: *What good answers! You are all right, and did you know that, while this plant is being researched to provide medicine for skin cancer, it is very poisonous, so don't eat it. The flowers only bloom when it is two years old, see how the younger plants only have one stem, and the older ones have two? The flower grows between the 'Y' of the two stems. The flower is white and the leaves are shaped in the…. What is this called?* [She holds the leaf for the children to see.]

Group 0: *Umbrella… whorled?*

Guide: *Yeah, the umbrella is whorled. Whorled is the word used to describe this pattern of leaves. When the flower matures, who knows why this plant makes a flower? The purpose and the reason?*

Group 0: *To make seeds, to attract a bee, pollination, reproduce.*

Guide: *Right again! And to feed the animals. Right? Even though this plant is poisonous to us, the fruit when ripe is not, and the Pennsylvania Turtle, sometimes a deer, will come along in late summer, early autumn and find a nice, fat, juicy berry.*

[Children look closer and express excitement and interest with sounds.]

Guide: *And who can tell me what that turtle does? When it finds that nice, fat, juicy berry?*

Group 0: [Now very excited, all chime in] *He eats it!!!!*

Guide: *That's right! Eats it! And then what?*

[The children are puzzled, not knowing what to say.]

Guide: *Well, he walks a little, he is a little turtle, so he does not walk far, and then, that is right—turtle droppings—it is the perfect fertilizer for a new plant to grow in! So, this plant and many plants rely on other animals to pollinate and then to plant their seeds. They make their flowers pretty and smell so they can attract bees and other insects to their nectar and pollen. They make fruit taste sweet so that animals will eat it and help to distribute seeds. And this is how the plants and animals are connected, it is a symbiotic relationship. Who can tell me about another 'symbiotic' relationship?...*

Note the emotional encouragement and confirmation that the guide gave to the children. There was positive reinforcement and approval throughout the hike, but it was never annoying or superficial. The bond that the children had with guide was based on respect for her knowledge and love for her kindness. They were eager to participate, and did not fear offering a wrong answer, so they felt safe taking many guesses. There was no risk for a mistake, as it was just kindly corrected and a new effort was encouraged. Facts, information, and stories were added and viewed as part of a normal, positive, constructive, and respectful dialogue. As seen in the example above, the guide's process was always to a question, get an answer, and to followed up with social acknowledgment (a reward), as well as more factual additions, demonstrations with as many senses integrated as possible, and finally a new question on the reason why or how, and so on.

Within the hour and a half field trip, the guide introduced concepts of importance, told stories, and answered questions. These were spontaneous, dynamic micro-lessons embedded in the activity inside a geo-spatial macro-context, representing the embodiment of the educational curriculum's ontology and integrated into the multi-sensory activity of a field trip. She relied on the abundance of material in the natural environment for content and context, maximizing the opportunities to weave the spontaneous finds of the moment, as well as student-initiated discussions into the larger lessons. Seemingly effortlessly, the guide was able to "spin" the curriculum's factual and conceptual ontology to meet the children's needs of the moment, based on their interest level, spontaneous events, or guide-initiated finds.

Ethnographic Observations of the Virtual Field Trip

The virtual field trip occurred at the University of Pittsburgh, School of Information Sciences PC computer lab classroom (Figure 5). This classroom is typical of many school computer labs, with workstations positioned in rows on desks and a projector system in the front of the room. Each virtual field trip group had six students, and each student had access to their own PC with a one-eared headset, keyboard, mouse, and the Virtual Trillium Trail software installed. The naturalist guide covered the same educational unit as in the real field trips. However, each student's experience was different at the micro-lesson level, as they each traveled on different paths, and found different plants and flowers. The guide controlled her PC and projected her system's images to a large screen in the front of the class.[2] In this way, the guide and students could share information at all times. Parents and the researcher were able to sit behind the children to passively observe and videotape.

Figure 5. Photographs from the virtual field trip, Virtual Trillium Trail, at the School of Information Science, University of Pittsburgh, May 2007

[2] This configuration is no different from the current state of technology in PC classrooms today. The instructor PC and projector was purchased and installed for under $5,000, and each student workstation cost between $1,000 to $2,000.

None of the children required training or assistance as they all knew how to use a PC, mouse, and keyboard. As soon as they entered the room, they sat down and started to explore independently and without instruction. The basic commands were "move forward" with the keyboard arrow key, and pan left, right, up or down with the mouse. Furthermore, many of them knew special commands found in gaming software, and started to walk (Ctrl-W), run (walk that was accelerated), fly (Ctrl-F), jump (Ctrl-J), and swim (walking into the water creates splashing and water sounds) through the virtual environment. They ignored the natural constraint of the path; this activity was very different from the real field trip, where they showed restraint. Most notably, within moments each child was virtually in very different locations—in the stream, on Lookout Rock, on the ridge, in the floodplain, in a tree, flying through the sky, or jumping down the waterfall—and each was asking questions about their virtual environment at the same time. The guide had to be active, answering each child's question as needed. At times, she made efforts to pull the group together, but was only able to get them to glance up from their PCs to look at the projected image, listen to her information and answer her questions for a moment before returning to their explorations. The guide's stories were the same, but the children were not in the same—virtual—place as the guide; they were in their own unique, personal, virtual place.

Although the rate of exploration, discovery, and activity, was faster than on the real trip, the control of pace and direction by the guide was gone. Now, instead of leading the children, as she had done in the real field trip, she was following them—virtually—and following each of the six simultaneously. This was a critical difference for the teacher and style of learning activity. In the lab there was fast, highly individualistic exploration with individual, rather than group, spontaneous finds. At times, the students did share their finds with the class and the guide, but this was only possible if their peers were not too involved in their own adventures.

The following example from the research notes is representative of the type of conversation observed during the virtual field trip in the PC lab.

> Guide: *OK, first I am going to fly up into the sky to get a view of the valley, you can follow me on your PCs if you want or you can just watch up here. So, what do you see?* [Guide navigates up for an aerial view of the valley.]
>
> Group 0: *The river. The valley. The tops of the trees.*
>
> Guide: *That's right. The name of the stream is Stony Creek and it is a tributary of Squaw Run, and Squaw Run is a tributary of what river?*
>
> Group 0: *Oh, Oh, Allegheny! Yes, the Allegheny River!*
>
> Guide: *That's right! And the Allegheny River flows into the what?*
>
> Group 0: *Oh, Oh, Monongahela, no the Ohio, then the Mississippi, then into the Gulf of Mexico, the Atlantic Ocean, then all over the world.*

Guide: *That's right! Stony Creek, Squaw Run, the Allegheny, the Ohio, the Mississippi, the Gulf of Mexico, and the Atlantic, so we are standing, well virtually flying, over the head-waters to the Mississippi!   Isn't that amazing! … What is a watershed and why is it important?*

Group 0: [Not sure, a bit reserved, some guesses] *Plants and animals need water to live.*

Guide: *Yes… And?… So the plants and animals need water to live,… and a watershed is a place—a land formation—that naturally collects rain water, like a bowl or a basin and then the rain water flows down the sides of the valley into the streams and rivers at the bottom of the valley.*
…
Did you know that we only have valleys here, and not hills? It is called the Appalachian Plateau. The streams and rivers have over time, a long time, eroded the valleys. The plants' roots help to hold the soil to the earth, and help to prevent severe erosion. The plants' roots also help to filter and clean the water to make it pure.
…
So, we can also see what plants like water—see the ones close to the streams—like this… this Sycamore Tree, it likes the water, has a white flaky bark. [The guide pointed to one of the trees that is visibly white and green, and not brown and green like the others, from above.] *We can fly down into the forest to take a closer look.* [The guide starts to fly down into the forest.]
…
This is the forest canopy, the tops of the trees. [The guide stops at a close-up of the tree leaves.] *What do you notice about the different leaves here? What does the bark look like?*

Group 0: *White and flaky.*

Guide: *What animals do you think make their homes up here?*

Group 0: *Birds, insects, squirrels, raccoons…*

The lessons were similar to the types of dialogue from the real field trip but made use of the flying feature to show the watershed from a different perspective. It also allowed the guide to take the children into the leaf canopy of the trees and to see things that they could not see in the real forest. Another difference was that the virtual perspective of the ground was much closer to the flowers than in the real field trip, so all of the flowers' structures were magnified and in view for analysis.

S7: *Oh look I found a field of Bluebells!!!*

Group 0: *Where?!?*

S7: *Here in the floodplain at the bottom of the valley.*

Guide: *Oh good! Let me see.* [The guide approaches the student and looks over at her PC.] *Hmm, I think those are actually Bluets. See, they are very small, and have only four petals. There are some violets too.*

Group 0: *Where are they? How do I get there? I found it! There they are, and there are some Trilliums too!*

Guide: [Takes some time to find the Bluebells on her PC] *Look up here, here are Bluebells, see how the petals are shaped in tubes, how they hang down in clusters. Now look at her screen, see the Bluets, they are small, and have almost flat petals positioned in opposites and there are only four petals for each flower. It is a really good find, and now we all know the names of two blue flowers! Bluets are smaller with four petals, and Blue Bells are larger with clustered, hanging tubes. Thank you, number 7.*

In an asynchronous way, the group interacted with their finds, their peers' finds, and the guide. From the perspective of an observer, it felt disjointed, yet individualistic. There was, of course, no smell, taste, touch, or the truly spontaneous finds of insects, animals, or birds in the virtual field trip as there was in the real, but the software allowed for full freedom of individual movement and supported independent exploration, discovery, and inquiry.

Posttest on Educational Facts (*N*=6)

A posttest on facts was administered after the students' first field trip, whether real or virtual, to measure any learning differences. The total posttest descriptive data for the real field trip (M = 30.09, SD = 14.01) is similar to the posttest descriptive data for the virtual field trip (M = 31.95, SD = 18.41). The t-test result is nonsignificant, $t(10) = 0.196$, $p = 0.849$, two-tailed. A Mann-Whitney U-Test, as a more conservative statistic due to the skewed distributions and small sample size (Siegel 1956, 62), still indicates no significant difference in total test scores: U = 16, N = 6, $p = 0.818$.

H_0: M Posttest $_{\text{(Real Field trip)}}$ = M Posttest $_{\text{(Virtual Field trip)}}$

The test was evaluated on total points possible (0-100 points), and the questions were classified into three categories. The first and most straightforward category dealt with *Facts* (*Real M* =13.99 and *Virtual M* =11.94). The second category dealt with *Concepts* (*Real M* =2.98, *Virtual M* =4.00). The last category dealt with affective aspects, which included the drawings, values, and the essays (*Real M* =13.16, *Virtual M* =16.00).[3] The data on the posttest indicated that for both groups, teacher expectations were exceeded (Expectation M = 2 < virtual group posttest facts M =11.94 < real group posttest facts M =13.99). As a volunteer group there may be sample bias, and the pre-experience profile showed high ranks for *Enjoyment of Nature*.

[3] Subjects 5 and 6 did not complete the drawing or the essays, thus damping the descriptives for that group.

Thus, the two groups had statistically identical profiles and posttest scores on educational facts after the first experience, so their behavior and response data were expected to be the same. Note that the tests only measured plants and content from the *Natural Communities* curriculum, and not all of the material that was encountered or learned, and so this result does not prove that all of the knowledge learned on the real field trip was captured or measured in the test, or that the environments or learning activity were the same. The real offered many experiences that were not in the virtual such as getting wet in the stream, finding and touching a salamander, smelling the Red Trillium or Skunk Cabbage, tasting a plant such as Garlic Mustard.

Interview Results (*N*=12)
As mentioned above, all subjects responded to an interview after experiencing both the real and the virtual field trips in order to compare and contrast the two experiences in qualitative depth. Below is a sample of a subject's answers to the interview.

Please answer the following questions:

1. What did you enjoy most on the Real Field Trip?
   I enjoyed the different plants and the waterfall.

2. What did you dislike most about the Real Field Trip?
   We needed to stop a lot if any of the kids had questions.

3. What did you enjoy the most in the Virtual Field Trip?
   Being able to fly around and drop to the ground.

4. What did you dislike the most about the Virtual Field Trip?
   It was very slow graphics.

5. How would you improve the Real Field Trip?
   If there were animals to see that would be better.

6. How would you improve the Virtual Field Trip?
   Make the computer faster and the graphics better.

7. Which Field Trip did you learn more from? What was it that you learned?
   The real one, because Gabi showed us a lot and talked about a lot of things with us. I learned the names of lots of plants and trees.

8. Describe your ideal Real Field Trip?
   It would be a hike through a forest with lots of plants and animals that we could touch.

9. Describe your ideal Virtual Field Trip?

It would be flying through a forest with lots of plants and even some monster plants, like skunk cabbages.

10. Describe how you felt in the Real Field Trip.
    I felt interested in the things around me and happy to be outside in nature.

11. Describe how you felt in the Virtual Field Trip.
    I felt like it was fun and something really different.

12. Which would you rather go on if you had a choice? Why?
    I would rather go on the virtual field trip because we can fly, and also because I can go at my own speed and stop and look at things or zoom on by.

The responses show interesting patterns and some surprising results. Half the students reported that what they enjoyed most on the real field trip was spotting plants, and half said it was being in the context of the environment. One-third reported that there was nothing they disliked about the real field trip, but a few mentioned that they got tired or did not like the bugs. When asked about what they liked most in the virtual field trip, the students responded individually: some were excited about the ability to fly, others with walking; some mentioned that they could use their imagination to pretend to become a hawk or a rabbit in the woods, while others cited the advantage of being able to see things from different points of view, or that all of the flowers were in bloom and they could learn about those flowers. When questioned about what they disliked the most in the virtual field trip, seven of the 12 cited slow response times (the PC lab had old equipment), four cited getting lost, and one reported difficulty in reading the plant fact note cards.

The students suggested improvements for both field trips. The ideal real field trip would include more animal sightings. Interestingly, the same suggestion held for the virtual field trip; students also wished for the ability to touch, smell, and taste in the virtual experience. They also suggested improved speed, interaction rates, and orientation capabilities for the virtual field trip. Two students made suggestions for new functionality. They suggested collaboration components in the forms of a virtual guide, avatars to represent themselves and friends, and also the ability to become a hawk, rabbit, or fish avatar.

More students felt more excited and interested in the virtual (n = 8) than the real (n = 4) field trip experience, but overall positive emotions of happy, calm, peaceful, interested, fun and excited were reported. Subject 10 said, "Everything cool, great! Would love to do it (both real and virtual) again!" Only one student reported disinterest, and that was for the real field trip. When asked which field trip they learned more from, ten out of 12 (83 percent) answered the real. But, when asked which field trip they would rather go on and why, more reported in favor of the virtual (n = 8) than the real (n = 3), with one not responding. Thus, even though they reported more *Learning* on the real trip, they would rather repeat the virtual one.

Significant Survey Results in Favor of the Real Field Trip
The post-experience attitudinal survey assessed 14 dimensions listed below in Table 1 and Table 2. It used a 5-point Likert Scale (1 = Not at all, 2 = Somewhat, 3 = Average, 4 = Mostly, 5 = A great deal) to compare and contrast the subjective perceptions of the real and virtual field trip experiences across each dimension. A non-parametric Wilcoxon Signed Ranks Test demonstrates the relative within-subject rank order for each experience, real and virtual, enabling a comparison of the two experiences. The researcher found three statistically significant dimensions: *Learning*, *Inquiry* and *Presence*.[4]

Learning is rated as significantly higher in the real than in the virtual experience (Table 1), supporting the interview results, but in contradiction to the posttest results. Learning was felt to occur in the virtual experience "Somewhat" (median 2.0). This ranking, framed in a direct comparison to the real experience, is the first known such comparison in terms of discovery-based learning. *Learning* was perceived as occurring in the real field trip "Mostly" to "A Great Deal" (median 4.5). This study has shown that while there is a student perception that more was learned in the real field trip, there is no statistical difference between the two experiences on a posttest for in-curriculum material.

However, the test only measured the learning of in-curriculum material, namely, information about watersheds, forests and plants. There was more in- and out-of-curriculum material embedded in the real field trip, and the children certainly learned more out-of-curriculum information in the real field trip. The posttest simply did not capture all information learned.

Significantly, there were unplanned learning events in the real field trip that were not duplicated in the virtual field trip, and not tested in the posttest. The following excerpt from the real field trip ethnographic observation introduces this idea of the "Salamander Find as a Salient Event."

> *…in the real field trip a female student was walking in the stream, she said to a friend that there was 'no life' in the stream, at which point the guide spun around and playfully said 'Oh yeah?' The child was surprised, taken aback, all of the other children froze and watched, but once regaining her composure, the student said, 'well that is what my mom told me, there is nothing alive in these streams.' The guide proceeded to bend down, pick up a rock, turn it over and find a real, live salamander. At which point all of the children gasped, surprised, and gathered closely around the guide, asking questions, getting answers and taking turns touching the small creature. The guide then related the life of the salamander to the health of the stream, and the health of the stream, as it was clean of pollution and run-off, to the watershed, nature reserve, and the healthy forest ecology. She pointed to*

[4] Due to the high number of hypotheses tested (14), a more conservative interpretation would be to reduce the *p*-value to 0.001 from the reported *p*-value of 0.05. In this more conservative view, there is no difference between the real and virtual experiences.

the banks and showed how they were well-composed from the abundance of plant, shrub, and tree roots. The relationship connecting the life of a beautiful, glistening-auburn salamander in hand to the health of the watershed was a powerful way to tie the experience back to the lesson on plants and to correct the child's misconception.

The "Salamander Find as a Salient Event" speaks to the critical claim that this sort of out-of-curriculum information is important for learning as it may provide salient "anchors" in long-term memory from which the in-curriculum material can be linked and activated. A finding of this study is that the posttest scores were statistically identical, yet the perceived dimension of *Learning* is significantly higher for the real field trip.

There is also a significant difference in survey data for the *Inquiry* dimension (Table 1). Here *Inquiry* is associated with asking questions, which is a very important activity in any educational learning environment, real or virtual. *Inquiry* rated higher in the real than in the virtual experience. This seems to contradict the observation in the lab that the rate of questions went up. However, as the guide had to jump from one question to the next, and physically run around the room because each of the six children was in a different location in the virtual environment, the students' perception of having their questions answered could have gone down as a result. Further, the salamander find stimulated a lot of *Inquiry* and that salient event only occurred in the real experience.

Finally, it is of no surprise that *Presence* rated higher for the real field trip than for the virtual. The clustering of features of *Inquiry* and *Presence* which coincide with *Learning* is important to investigate in future work.

Table 1. Real superior to virtual: reported value and the Wilcoxon Signed Ranks (*N* = 12)

Real superior to virtual ($p < 0.05$)	Real		Virtual		Wilcoxon (two-tail)
	Reported	Median	Reported	Median	*p*-value
Learning	"Mostly – A great deal"	4.50	"Somewhat"	2.00	0.010
Inquiry	"A great deal"	5.00	"Mostly"	4.00	0.026
Presence	"A great deal"	5.00	"Somewhat – Average"	2.50	0.017

Survey Results Showing No Statistical Difference between Field Trips

H_0: *M Real* Attitudes = *M Virtual* Attitudes

Interestingly, in all other dimensions, there is no statistical difference between the ratings of the real and virtual trips. The data in Table 2 below show the reported values, median, and *p*-value, ranked from highest to lowest by the order of the virtual median value. The highest ranked value is for *Exploration* (Median = 5.0, "A great deal"), and the lowest is for *Disinterest* (Median = 1.0, "Not at all"). From a software design standpoint, this is exciting and encouraging data, as the "gold standard" of parity with the real experience was obtained in these dimensions.

The evidence that the virtual trip matched the real one for these dimensions, and in an order that is desirable for usability, is encouraging for future software development. The other high rankings (Median > 4, "Mostly" to "A great deal") are in: *Desire to Create*, *Sense of Excitement*, *Level of Curiosity*, *Desire to Re-experience*, and *Sense of Calm*. This is an interesting cluster for the design of virtual field trip software and deserving of deeper investigation in the future. Furthermore, the Wilcoxon Signed Ranks statistic is a conservative measurement of the data. The *p*-values in the dimensions of *Exploration*, *Desire to Create*, and *Re-experience* ($p < 0.20$), and *Frustration* ($p < 0.10$), are worth a closer inspection and future work.

Table 2. No statistical difference between real and virtual ratings of the Wilcoxon Signed Ranks (N = 12)

No difference ($p > 0.05$)	Real		Virtual		Wilcoxon (two-tail)
	Reported	Median	Reported	Median	*p*-value
Exploration	"Mostly"	4.00	"A great deal"	5.00	0.196
Desire to Create	"Mostly-A great deal"	4.50	"Mostly-A great deal"	4.50	0.139
Sense of Excitement	"A great deal"	5.00	"Mostly-A great deal"	4.50	0.453
Level of Curiosity	"Mostly-A great deal"	4.50	"Mostly"	4.00	0.670
Re-experience	"Average"	3.00	"Mostly"	4.00	0.163
Sense of Calm	"A great deal"	5.00	"Mostly"	4.00	0.395
Desire to Share	"Average"	3.00	"Average-Mostly"	3.50	1.000
Awe and	"Mostly"	4.00	"Average"	3.00	0.577

Wonder					
Assessment of Beauty	"Mostly"	4.00	"Average"	3.00	0.257
Level of Frustration	"Not at all"	1.00	"Somewhat"	2.00	0.098
Disinterest	"Not at all-Somewhat"	1.50	"Not at all"	1.00	0.389

Discussion

The ethnographic study of the real field trip and the virtual field trip represented a research opportunity in education as well as in user-centered software design and development. The unique value of the real field trip is clearly the integration of many senses, and students' ability to develop intellectual and emotional connections to their world in context. The real field trip observed here was guide-led and on a linear path through the woods, yet it was open to spontaneous finds, student discovery and inquiry, especially in moments of surprise. The main educational value is the leveraging of episodic memory with "salient events." The surprise salamander find was such a salient event, documented here as an environmental trigger for a "teachable moment" (Bentley 1995). The skilled guide seized the moment and spun the ontology of the curriculum around that event for maximum effect.

The main value of the virtual field trip is that the PC computer lab transcended time, space and distance, and the students were able to virtually explore a park with success. Additionally, the guide could manipulate the frame of view for a holistic representation of the space from above, thus showing views that were impossible on the real field trip. The guide could also very quickly correct a student's misconception by using the software to show and compare. Furthermore, the virtual field trip allowed each child to explore independently, enabling each child to be in a different virtual space at the same time. The guide could also bring information to their attention on her large projected screen for a class discussion, although everyone was in a different virtual "place" at the same time. This style of teacher-student interaction is different from traditional styles and could be used to advantage for peer collaboration and sharing.

The posttest data on students' learning of facts showed no statistical difference between the real field trip and the virtual field trip. However, this posttest only covered content in the curriculum. There is abundant ethnographic evidence that supports the fact that students learned more of out-of-curriculum material in the real field trip. Further, the post-experience interview and survey showed statistically significant results ($p < 0.05$) that students perceived the real field trip to be superior to the virtual field trip for *Learning, Inquiry* and *Presence.* All of the other attitudinal dimensions—*Exploration*, *Desire to Create*, *Sense of Excitement*, *Level of Curiosity*, *Desire to Re-experience*, *Sense of Calm*, *Desire to Share*, *Awe and Wonder*, *Assessment of Beauty*, *Level of Frustration*, and *Disinterest*—were rated by students as statistically the same between the real and the virtual field trips, suggesting that a virtual experience can be designed to match a real one along these dimensions.

The main result of the study is that a virtual trip can be used for in-curriculum material with success, although a real trip is still a superior learning environment. The synthesis of both the ethnographic and the statistical data is to conclude that although posttest data may be equal, there were more salient events on the real field trip. Thus, students on the real trip perceived and sought more information than was measurable on a test, or than was programmed into the virtual experience. The inclusion of non-curriculum based but salient events in future virtual systems represents an interesting but important engineering challenge, considering the impact these may have on individual's perceptions of *Learning*, *Inquiry* and *Presence* in such systems.

Conclusion

This study demonstrates that both discovery-based field trip learning environments, real and virtual have educational contributions to offer. There is posttest and survey evidence that learning did occur in the virtual experience. This finding supports the claim that a virtual experience could be used when a real one is not available, but clearly the virtual should not replace the real if it is available. The students reported that more learning occurred on the real trip, but that they would rather repeat the virtual one. Interesting future research should explore how the two experiences might be combined to act in a complementary fashion. For example, a virtual trip could be used before a real one to prime the students, and/or after a real one to reinforce learning.

The study has some limitations. First, there are issues in generalizing the findings to any socio-economic class different from the study group. Future work will investigate how different populations, such as urban and rural, respond to and use the Virtual Trillium Trial software. One option would be to offer the software in a traveling school bus equipped as a PC lab. Also, should trends on technology access continue, especially with respect to G3 cell phone technology and the corresponding rate of graphics processing power on small, hand-held devices, it is conceivable that virtual environments designed for devices such as the Apple iPhone will become accessible to new populations.

Second, the study's posttest had a small sample size (N = 6). However, the claim is that the groups were in the same school with the same curriculum, and ten of the 12 students were in the same class and all were of the same profile. Thus, there is a very high chance that they came to the experience with the same educational preparation, even without the hard evidence of a pretest. Admittedly, it would have been better to have had one. The use of a non-parametric Wilcoxon Signed Ranks Test for the survey comparison (N = 12) is sufficient for the measurements on both conditions, even with 12 students.

The main contribution of the study is the documented "Salamander Find as a Salient Event" on the real field trip. These types of environment-driven salient events will be a future research direction of high importance. It showed the importance of the “teachable moment” (Bentley 1995), with the guide dynamically adapting to context, child, and discovery on the spot with respect to the in-curriculum ontology. The fact that students ranked *Learning* as higher on the real trip in the survey suggests that the salamander find was a powerful salient event and a highly desired attribute of real field trips. This “Salient Event” also suggests that such surprises are important future user-interface design elements required for learning in virtual reality systems. Further, it suggests that the use of dynamic avatar guides could be developed and made to react to such salient events to maximize discovery-based teaching and to support the intrinsic learner.

Future work will analyze the empirical *in-situ* data for suggestions as to how the two experiences could work together in a complimentary fashion. Additionally, future work will investigate empirical evidence on connections between the environment, salient events, affective reactions and learning, to unlock the detail in the child-computer-environment interface.

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Appendix

Interview Questions

1. What did you enjoy most on the *Real Field Trip*?
2. What did you dislike most about the *Real Field Trip*?
3. What did you enjoy the most in the *Virtual Field Trip*?
4. What did you dislike the most about the *Virtual Field Trip*?
5. How would you improve the *Real Field Trip*?
6. How would you improve the *Virtual Field Trip*?
7. Which *Field Trip* did you learn more from? What did you learn?
8. Describe your ideal *Real Field Trip*.
9. Describe your ideal *Virtual Field Trip*.
10. Describe how you felt in the *Real Field Trip*.
11. Describe how you felt in the *Virtual Field Trip*.
12. Which would you rather go on if you had a choice? Why?

Survey Questions

First rate [1 to 5] for the Real Field Trip, then rate for the Virtual Field Trip.
1 = Not at all, 2 = Somewhat, 3 = Average, 4 = Mostly, 5 = A great deal

1. I was able to explore more in the (*Real* | *Virtual*) field trip.

2. I was able to inquire – ask more questions and get answers in the (*Real* | *Virtual*) field trip.

3. I was able to learn more in the (*Real* | *Virtual*) field trip.

4. I experienced a heightened sense of curiosity in the (*Real* | *Virtual*) field trip.

5. I experienced an emotional sense of calm in the (*Real* | *Virtual*) field trip.

6. I experienced excitement in the (*Real* | *Virtual*) field trip.

7. I experienced awe and wonder in the (*Real* | *Virtual*) field trip.

8. I experienced frustration in the (*Real* | *Virtual*) field trip.

9. I experienced disinterest in the (*Real* | *Virtual*) field trip.

10. I want to create something like what I experienced from the (*Real* | *Virtual*) field trip.

11. I want to share this experience (*Real* | *Virtual*) field trip with my friends.

12. Do you want to re-experience the (*Real* | *Virtual*) field trip?

13. Did you experience a sense of presence or of "being there" in the (*Real* | *Virtual*) field trip?

14. Did you experience a sense of beauty in the (*Real* | *Virtual*) field trip?