INQUIRY LEARNING IN MULTI-USER VIRTUAL ENVIRONMENTS

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Abstract

In this paper, we provide an overview of the design of an NSF-funded Multi-User Virtual Environment science curriculum project focusing on the creation of virtual experimentation methods and tools that go beyond a ‘canned lab’ approach to concentrate on inquiry, using novel pedagogies to help low-performing students master complex skills. We present findings from students and teachers on the effectiveness of these methods, tools, and virtual contexts in creating an experimental learning environment authentic to what scientists experience in their work.

Problem

For decades, science educators have worked to infuse inquiry into the K-12 curriculum (AAAS 1990, 1993; NRC, 1996). However, good scientific inquiry is both hard to design and hard to implement (The National Academies, 2005). This issue is compounded by the practice, particularly prevalent in urban schools, of having non-science teachers teaching science (Urban Teacher Collaborative, 2000). These teachers are untrained in experimental design and often rely on ancillary textbook materials to fulfill this need. Unfortunately, many of the inquiry activities associated with textbook materials are meant to clarify and confirm information already presented to students, rather than to provide true experimentation of complicated phenomena with unknown outcomes. In this paper, we provide an overview of an NSF-funded curriculum project that focuses on creating virtual experimentation methods and tools that go beyond the ‘canned lab’ approach to concentrate on inquiry about complex phenomena, using novel pedagogies to help low-performing students master these sophisticated skills. We then present findings from students and teachers on how successful these methods and tools are in creating an experimental environment authentic with the actual experiences of scientists.

Theoretical Underpinnings

Inquiry

The National Science Education Standards define scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work…also …the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (quoted in National Science Teachers Association, 2004). Responses to the NSTA position paper indicate that many teachers are unclear about how to implement inquiry in their classroom. Some teachers presume that traditional “cookbook” experiments promote inquiry learning for students (Wallace & Louden, 2002).

MUVE

To provide teachers with quality ways to address this issue, we have created River City, a multi-user virtual environment (MUVE) designed to teach scientific inquiry skills to middle school students. MUVEs enable multiple simultaneous participants to access virtual contexts, interact with digital artifacts (such as online microscopes and pictures), represent themselves through "avatars," communicate with other participants and with computer-based agents, and enact collaborative learning activities of various types (Nelson, Ketelhut, Clarke, Bowman and Dede, 2005). The River City curriculum is centered on skills of hypothesis formation and experimental design, as well as on content related to national standards and assessments in biology and ecology. The virtual "world" is a city, set in the late 1800's, and concentrated around a river that runs from the mountains downstream to a dump and a bog. Like most 19th century industrial towns, it contains various neighborhoods, industries, and institutions such as a hospital and a university.

Inquiry in the MUVE

The River City curriculum is carefully crafted to provide a level of complexity that occupies a 'middle-ground' between the simplicity of many classroom-based inquiry curricula and the complexity of real world scientific inquiry. With this in mind, the River City world has been designed with three different illnesses (water-borne, air-borne, and insect-borne) integrated with historical, social and geographical content, allowing students to develop and practice the inquiry skills involved in disentangling multi-causal problems embedded within a complicated environment (Nelson et al, 2005).

To aid in their quest, students (through their avatars) can engage with the virtual environment by interacting with computer-based agents (residents of the city), digital objects (historical images from the Smithsonian, video clips illustrating scientific processes), and the avatars of other students. In exploring, students also encounter various visual and auditory stimuli, such as mosquitoes buzzing and people coughing, that provide tacit clues as to possible causes of illness.

While exploring the River City world, students can also make use of several interactive tools designed to scaffold their inquiry, manage complexity, and mimic real-world scientific inquiry processes. Foremost among these is the virtual microscope. With this tool, students are able to test the quality of water in the town's rivers, wells, and bog (figure 1). Using other virtual tools, students can also run blood, fecal, and lice tests on local residents (figure 2).

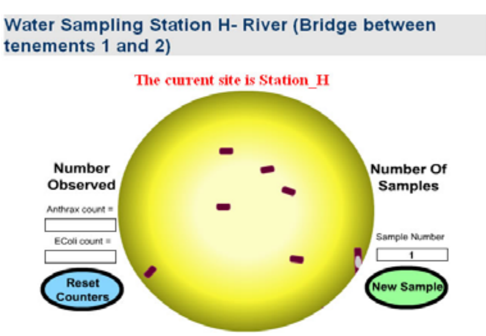


Figure 1: Water testing

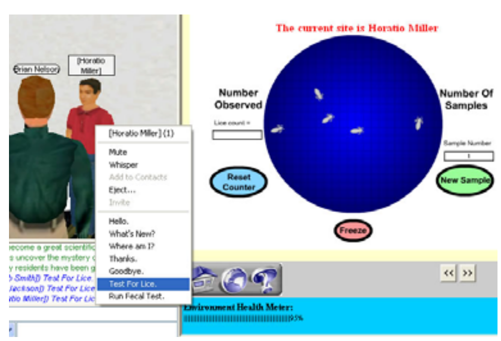


Figure 2: Lice testing

A unique aspect of River City is the ability for students to change a single factor in one of two identical worlds in order to view the impact, if any, that change had on a particular disease. After student teams design their own hypothesis about the cause of the illnesses, they choose an independent variable to alter in order to test that hypothesis. For example, students may decide that an insect and garbage-filled bog in River City is a source of illness, and decide to clean it up.

Students then compare the "control" and "experimental" worlds to see if their actions have had any effect on various factors, such as residents' illnesses, water pollution, or number of mosquitoes.

Design and Procedure

Research questions

The research questions on which this analysis is centered are:

1. Is student understanding of inquiry affected by whether experimentation is physical or virtual?
2. How do students and teachers view using virtual tools in a MUVE?

Student Population

This paper presents the results of a Fall 2004 implementation in a Mid-Atlantic state with a population of 500 students. Differing from our other implementations, this population only had a small percentage of ESL and free-and-reduced lunch students.

Procedures

The computer-based River City and a non-computer control treatment were randomly assigned to whole classes. The control curriculum (EI) includes features similar to River City, such as a historical scenario and unknown disease transmission. In addition to experimental design and analysis, this curriculum also includes physical experimentation. Each teacher in this sample offered both treatments. After designing and conducting their experiments, students were asked to write letters to the Mayor of the town in which they discussed their hypothesis, experimental design, results and recommendations for solving the city's health problem.

Both qualitative and quantitative data were collected from students and teachers over the three-week implementation period. Pre- and post-intervention, the students completed an affective measure that was adapted from three different surveys, Self-Efficacy in Technology and Science (Ketelhut, 2005), Patterns for Adaptive Learning Survey (Midgley, C. 2000), and the Test of Science Related Attitudes (Fraser, 1981). To assess understanding and content knowledge (science inquiry skills, science process skills, biology), we administered a content test, pre- and post-intervention. Upon project completion, students responded to five project evaluation questions.

To support teachers, we trained the science curriculum specialist in the district to conduct a professional development program, focused on content review, alternative pedagogical strategies based on different theories of learning, facilitation strategies while students are using the MUVE, and interpretive strategies for leading class discussions. Teachers responded to a pre- and post-questionnaire regarding their methods, comfort with technology, and reflections on using the MUVE in their science class.

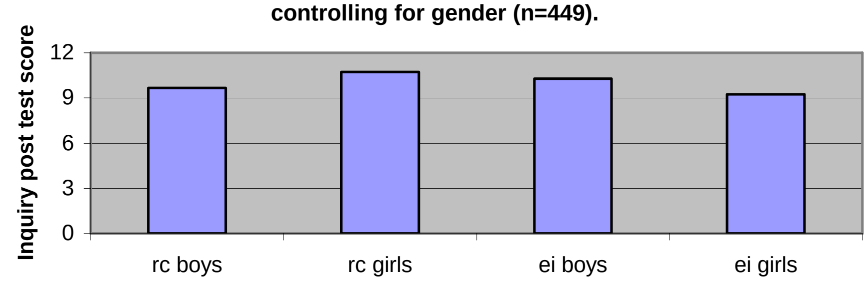
Findings

The quantitative data were analyzed with SAS, using a significance level of $p \leq .05$; checks for linearity, normality and homoscedasticity were performed at intervals with no violations found.

Results:

Our first research question asks whether student learning would be differentially affected by virtual versus physical experimentation. To determine this, we evaluated posttest scores for questions on inquiry comparing students in the River City curriculum with those in the control curriculum. The results of this analysis are shown in Figure 3. As can be seen, students posted similar scores, with the River City students scoring slightly higher on average (p<.01). This appears to indicate that students can learn inquiry in a virtual environment, not just a physical one, althought the effect does differ by gender.

Figure 3. The effect of treatment on inquiry post test score, controlling for gender (n=449).



Key:

rc = River City curriculum

ei = Control curriculum

Our second research question asks how students and teachers view virtual experimentation. At the end of the implementation, students are asked to evaluate the project. One of the questions asks students to "List 3 things you liked about the science investigation project you just used in your science class." This is an open-ended question, and students are not guided to think of any specific aspect. As might be expected, students talk about the fun of using the computer, communicating with their teammates, etc. However, many students also list specific aspects of River City specifically that made the project enjoyable for them. The results of these are shown in Table 1.

Table 1. Percent of students in the October, 2004 implementation who chose to volunteer specific features of River City in their answer to "List 3 things you liked about the science investigation project you just used in your science class" (n=407).

Feature mentioned	Number of students	Percent of students
Aspects of inquiry	**194**	**50%**
Tools for experimenting	**119**	**31%**
"Like real life" or "Like being a scientist"	**29**	**8%**
Better or different from science class	**17**	**5%**

Surprisingly, 50% of the students listed some aspect of scientific inquiry as a key feature of the project for them. Nearly a third specifically listed virtual tools, such as the virtual microscopes or the health meter, while a small but distinct group emphasized the authenticity of the experience.

The five teachers in this implementation were well versed in using inquiry in their classroom and as such, we viewed them as a particularly tough audience to sell on virtual experimentation. Results of the teacher post-survey questions on this topic are shown in Table 2.

Table 2. Teacher responses to using River City in their classroom (n=5)

Effect of using River City as stated by teachers in their post-evaluation	Identified feature	Number of teachers
Raised student awareness of inquiry		**4**
Improved student understanding of Scientific Method		**5**
Improved student understanding of how diseases are spread		**5**
Most important element	Student-centered experimental design	**5**
Most instructionally valuable element	Multivariate nature of investigation	**1**
	Testing	**1**
	Development of research skills	**4**
Best "ah-ha" moment for students	Changable worlds	**2**
	Data collection	**2**
	More than 1 disease	**1**

As can be seen from this, these teachers were very approving of the effects of the project; four of them specifically mentioned that the inquiry aspects that are the focus of this analysis were the best "ah-ha" moment for students. The fact that this population of lab-centered teachers was not worried with having virtual experimentation is very positive.

Conclusion

Scientific inquiry is a difficult construct for teachers to implement without support, and the current emphasis on content coverage via high stakes tests often reinforces presentational pedagogies. In addition, access to laboratory materials is often limited. Educational MUVEs offer a promising vehicle to increase student participation in context-based inquiry. Our analysis is demonstrating that the design of our River City MUVE curriculum and inquiry tools has been successful in substituting for physical experimentation and in helping students engage with and learn about inquiry.

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