INQUIRY TEACHING FOR DEPTH AND COVERAGE VIA MULTI-USER VIRTUAL ENVIRONMENTS

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Abstract

This National Science Foundation funded study is investigating novel pedagogies for helping teachers infuse inquiry into a standards-based science curriculum. Using a Multi-User Virtual Environment (MUVE) as a pedagogical vehicle, teams of middle school students are asked to collaboratively solve a simulated 19th century city's problems with illness, through interaction with each others' "avatars", digital artifacts, tacit clues, and computer-based "agents" acting as mentors and colleagues in a virtual community of practice. This paper describes the results from the first of three implementations in 2004 with more than 1000 students from geographical diverse urban areas. Results indicate that our curriculum is motivating and improves content knowledge and inquiry skills as compared to a similar paper-based curriculum.

Problem

For decades, science educators have worked to infuse inquiry into the K-12 curriculum (AAAS 1990, 1993; NRC, 1996). For example, the National Science Teachers Association recently issued a draft position statement recommending the use of science inquiry as a method to help students understand the processes and content of science (National Science Teachers Association, 2004). This goal is problematic for teachers when juxtaposed with requirements of preparing students for the detailed science content included in high stakes testing. Curricula centered on both inquiry and coverage of state and national content standards are needed. In this proposal, we provide an overview of early results from a large-scale implementation this past May of an NSF-funded curriculum project that focuses on both these objectives, using novel pedagogies to help low-performing students master complex inquiry skills.

Theoretical Underpinnings

What is "inquiry?" The range of possible responses to this question is large. Some refer to inquiry as a set of process skills that include questioning, hypothesizing and testing while others equate it to "hands-on" learning. The National Science Education Standards defines 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). Inquiry, according to Hinrichsen & Jarrett (1999), consists of 4 elements (pg. 7):

- Connecting personal understandings with those of sound science
- Designing experiments
- Investigating phenomena
- Constructing meaning from data and observations

These are straightforward suggestions that become increasingly problematic to implement as teachers attempt to infuse coverage of mandatory content with inquiry, since active learning by students is much more time consuming (yet much more effective) than passive assimilation. Additionally, responses to the NSTA position paper indicate that many teachers are unclear as to how to implement inquiry in the science classroom. Some presume that traditional “cookbook” experiments promote inquiry learning for students (Wallace & Louden, 2002).

Our project studies how a technology-intensive learning experience that implements problem-based inquiry science curricula can provide both deep inquiry skills and content coverage. In particular, we are working to dramatically improve the educational outcomes of the bottom third of students, pupils who even by middle school often have given up on themselves as learners. These students are disengaged from schooling and typically are difficult to motivate even by good teachers using conventional inquiry-based pedagogy. We are investigating whether educational Multi-User Virtual Environments (MUVEs), which resemble the entertainment and communication media students use outside of school, can reengage them in learning. MUVEs enable multiple simultaneous participants to access virtual contexts, to interact with digital artifacts, to represent themselves through “avatars,” to communicate with other participants and with computer-based agents, and to enact collaborative learning activities of various types. This last we use to create a community of inquiry learners.

Our “River City” MUVE is centered on the four inquiry skills listed above, as well as on content related to national standards and assessments in biology and ecology. The virtual “world” consists of a city with a river running through it, different forms of terrain that influence water runoff, and various neighborhoods, industries, and institutions such as a hospital and a university. The students themselves populate the city, along with computer-based agents, digital objects that can include audio or video clips, and the avatars of instructors (Figure 1). Content in the right-hand interface-window shifts based on what the participant encounters or activates in the virtual environment (Figure 2).

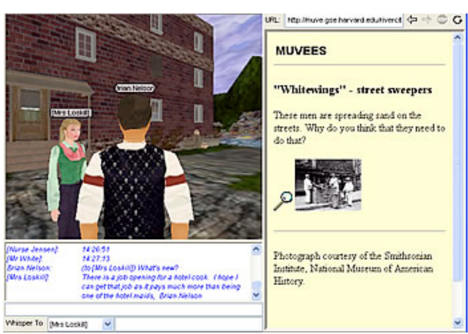

Figure 1

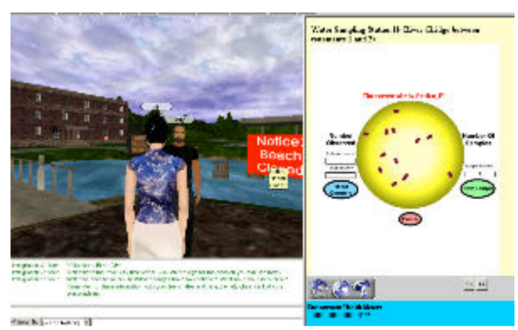
Figure 2

In River City, students work in teams to develop hypotheses regarding one of three strands of illness in the town (water-borne, air-borne, and insect-borne). These three disease strands are integrated with historical, social and geographical content, allowing students to experience the inquiry skills involved in disentangling multi-causal problems embedded within a complex environment. At the end of the project, students compare their research with other teams of students in their class to delineate the many potential hypotheses and causal relationships embedded in the virtual environment.

In order to explore the type of learning best supported by MUVEs used for inquiry learning, we developed two variations of the River City curriculum for this implementation. Variant GSC centers on a guided social constructivist (GSC) model of learning-by-doing, in which guided inquiry experiences in the MUVE alternate with in-class interpretive sessions led by the teacher.

Variant EMC shifts the learning model to a situated pedagogy with expert modeling and coaching (EMC), based on expert agents embedded in the MUVE. These two River City variants were compared to a "control" condition that utilized a paper-based curriculum in which the same content and skills were taught in equivalent time to comparable students without using computers, via a guided social constructivist-based pedagogy. This type of control curriculum enables us to focus on the strengths and limits of MUVEs, as well as the types of pedagogy best supported by this medium.

Our long-range goal is to develop "replacement" units that—through simultaneously developing students' knowledge in science, mathematics, history, and social studies—enable teachers to utilize inquiry methods while covering the same span of content in a similar amount of time (as contrasted with presentational teaching of this material one topic at a time). Given current educational reforms that at worst can lead to a crowded curriculum driven by high-stakes tests, evolving science teaching to new forms of inquiry teaching is essential.

Design and Procedure

Research questions

The research questions on which this analysis is centered are:

1. When compared to the "control" version, what types of significant gains in affect and learning for both content and inquiry do versions GSC and EMC produce? Do the gains from each version correlate with various types of student attributes?
2. What are MUVEs' strengths and limits in facilitating classroom-based inquiry learning?

Student Population

We conducted large-scale implementations of more than 1000 students in a major urban area in New England and one in the Midwest; schools in these two areas had high proportions of ESL and free-and-reduced-lunch pupils.

Procedures

The two computer-based variants (GSC and EMC) were randomly assigned to students within each classroom, with teachers instructed to minimize cross-contamination of treatments. A third, paper-based control treatment was randomly assigned to whole classes. Each teacher offered both the computer-based treatments and the control.

After designing and conducting their experiments, students in both the control and River City treatments were asked to write letters to the Mayor of River City 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). This modified version has scales to evaluate students' efficacy of technology use (videogame, computer, chat, etc), science efficacy, thoughtfulness of inquiry, science enjoyment, and career interest in science. To assess understanding and content knowledge (science inquiry skills, science process skills, biology), we administered a content test, (with sections modified from Dillashaw and Okey, 1980), pre- and post-intervention.

We conducted semi-structured interviews with 12 students (six boys and six girls) pre-, during, and post-intervention. The students were chosen by their teacher and represented both low and high achievement. Interviews were conducted in the school during the students' free period. All interviews were audio recorded and transcribed verbatim.

To support teachers, we created an online 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. The teachers collected demographic data and rated their expectations of students' successes and motivation with the project. Log files of individual student activity in the MUVE were captured for all students in test classrooms. 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 was analyzed with SAS. Descriptive statistics, correlations and regression models were run. A significance level of $p \leq .05$ was used; and checks for linearity, normality and homoscedasticity were performed at intervals. No clear violations were noted.

Affective results:

For some of our implementation sites, the question of pedagogy and curriculum is meaningless as many students are rarely in class to experience it. In some of those classrooms, we found that student attendance improved and disruptive behavior dropped during the three-week implementation (Nelson et al, 2005).

We were also interested in characteristics that promote scientific interest and inquiry. For example, on our affective measure test, we measured *thoughtfulness of inquiry,* a measure of metacognitive awareness. Student scores on this subscale on the post-survey were significantly higher ($p<.01$) on average for River City students, in comparison to the scores for students in the control group. For example, River City students scoring an average of 1 (strongly disagree) on the scale of 1-5 for the pretest were associated with scores of 1.8-1.9 on the posttest, nearly double their starting average score. Students in the control group also improved, on average, but only to 1.3. Another subscale measured *interest in a scientific career*; the gain in interest in science careers was 5% higher for students who had taken part in the River City curriculum than for those who had completed the control curriculum—a substantial gain for a 2-week implementation!

Biology Content Results:

Of the nearly 300 students who have been analyzed to date in implementation one, students in the River City experimental treatments improved their biological knowledge by 32%-35%. Control students also improved, but by only 17%.

Inquiry Content Results:

Our research questions for this implementation revolved around whether using a technology-based inquiry project could improve inquiry learning for students and support teachers teaching with inquiry. When using survey questions to assess inquiry, we found equivocal results. Improvements were seen across the board for knowledge and application of scientific processes; control students improved slightly more than the other two groups: 20% for the control, 18% for the GSC group and 16% for the EMC group.

Since we felt that it was difficult to measure inquiry with a multiple-choice test, we also analyzed students' "letters to the mayor" for evidence of Hinrichsen & Jarrett's (1999) four inquiry elements. Since detailed comparison of the letters from the River City curriculum and the control curriculum may not be productive, as it is harder to conduct an experiment on paper, we looked for similar demonstrations of student understanding of the processes of inquiry and for motivation. The letters written for the control curriculum often: were much shorter in length, did not demonstrate motivation or engagement, did not mention the experiment, and did not explicitly recognize the interconnectedness of the chosen problem with other possible causes of the larger problem. Analysis of the letters' evidence of inquiry found that students taking part in the MUVE-based curriculum earned scores more than double that of their paper-based control peers, on average ($p<.01$).

Further analysis of students' letters to the mayor of River City suggest that students demonstrate an understanding of the process of inquiry that was not well captured in the science inquiry post-test measures. For example, students who scored low on the science inquiry post-test wrote letters that were of similar quality to those written by students who scored higher on the post-test. As one illustration, in their letters low-performing content students matched the high-performing content students around criteria of stating an opinion regarding the cause of the problem and/or the outcome of the experiment. In addition, in their letters both low- and high-performing students demonstrated a clear causal relationship between the problem and the reason(s) for the problem.

Interestingly, more of the lower-performing test students met the criteria of providing suggested interventions or further research than students who scored higher on the inquiry test questions. This suggests that the complexity of the MUVE treatment creates intricate patterns of learning more appropriately measured with an authentic activity, such as writing an experimental report.

We also analyzed the results of interviews and focus groups, looking for evidence of inquiry. Many students claimed they felt like a scientist for the first time in science class because they were "doing tests and stuff to see what was causing the sickness" (Clarke and Dede, 2005). River City has an online microscope and a bug catcher tool that students can use to take water samples and count the number of mosquitoes in an area. These tools helped students feel like they were "actually conducting an experiment." Having to come up with a hypothesis and design an experiment was motivating. Being able to "pretend to be a real scientist" allowed some students to take on a new identity as an effective science learner.

River City versus the Control Curriculum on Improving Inquiry:

Can River City facilitate teaching with inquiry from the perspective of the teacher? We are just beginning the analysis of the 25 teachers involved in the project; however, initial analysis seems to indicate it does. For example, one teacher reported that "Students seem to learn more deeply about science and problem solving in the simulation or manipulation setting than in traditional book education, as evidenced by their class discussions" (Galas & Ketelhut, in press).

Students seem to enjoy the inquiry pedagogy and like that it is "more independent working…rather than having him instruct us and telling us what to do and guiding us." They claim, "it was different by exploring by myself not being told what things to test out." According to one student, "when I was making the experiment and going around asking everything I kind of felt like a detective." Many students said that they liked the fact that it was more "difficult" and "more challenging" than their regular science class. Having to solve the problem and "figure out" why people were getting sick made students "think more" and as a result, learn more. One student claimed, "we had to figure out things and ask questions and use our brains and think really hard... because we had to figure out what was wrong."

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. Our project is showing that MUVE-based curricula can teach standards-based biological content infused with complex inquiry skills better than good traditional approaches do. While analysis of this sizable dataset is still underway, our preliminary findings show that students learned biology content, that students and teachers were highly engaged, that student attendance improved, that disruptive behavior dropped, that students were building 21st century skills in virtual communication and expression, and importantly, that using this type of technology in the classroom can facilitate good inquiry learning.

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