Design-Based Research on Gender, Class, Race, and Ethnicity in a Multi-User Virtual Environment

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Abstract: This National Science Foundation funded project utilizes graphical multi-user virtual environments (MUVEs) as a vehicle to study (1) classroom-based situated learning and (2) the ways in which virtual environments may aid the transfer of learning from classroom contexts into real world settings. In the project's River City curriculum, teams of middle school students are asked to collaboratively solve a simulated 19^{th} 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 impact of this intervention on sub-populations of students. In implementations in several cities, we have seen no gender or racial differences in student success.

Keywords: technology, situated learning, inquiry, virtual environments, gender, race.

INTRODUCTION

Scientific literacy—the capabilities (1) to understand the interrelationships among the natural world, technology, and science and (2) to apply scientific knowledge and skills to personal decision-making and the analysis of societal issues—is a major goal for education in the 21^{st} century (AAAS, 1993; NRC, 1996). Research suggests that, if all students are to become scientifically literate citizens, science instruction must convey greater engagement and meaning to them. Currently, only 5% of all doctorate-holding scientists are either African-American or Hispanic; only 25% are women (National Science Foundation, 2001). One hypothesized factor in these low numbers stem from choices students make in secondary school. Both racial minorities and girls begin to opt out of science courses as early as middle school as result of increasing negative attitudes conveyed to them about their potential capabilities as learners and practitioners of science (Clark, 1999; Farenga & Joyce, 1998). By the time these students reach college, they have limited their choices of majors to non-science/non-math fields as a result of their backgrounds and attitudes. As our society becomes more dependent on new discoveries in technology and science, and on citizens making wise decisions about policy issues related to science, this 'science divide' will become more problematic. To combat this, we believe that science instruction in secondary schools must provide students with opportunities to explore the world; to apply scientific principles; to sample and analyze data; and to make connections among these explorations, their personal lives, and their communities. However, given the constraints of classroom settings, real world data collection is challenging to orchestrate. Laboratory experiments are also difficult to conduct due to lack of equipment and safety issues. It is no surprise that teachers report that higher order inquiry skills such as hypothesis formation and experimental design are among the most difficult challenges they face with students who have a history of low achievement in science.

With prior NSF funding, we have created and studied graphical multi-user virtual environments (MUVEs) that use digitized museum resources to enhance middle school students' motivation and learning about science and society (http://www.gse.harvard.edu/~dedech/muvees/). Multi-user virtual environments 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. Our "River City" MUVE 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.

Pilot Studies

The initial pilot study of our project's 'River City' educational environment extended typical MUVE capabilities in order to study the science learning potential of immersive simulations, interactive virtual museum exhibits, and "participatory" historical situations. Our goal was to promote learning for all students, particularly those unengaged or low performing. Using a guided social constructivist design, students learned to behave as scientists while they collaboratively identified problems through observation and inference, formed and tested hypotheses, and deduced evidence-based conclusions about underlying causes.

The River City 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 (muve.gse.harvard.edu/muvees2003). The learners 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). Dialogue is shown in the text box below these two windows; members of each team can communicate regardless of distance, but intra-team dialogue is displayed only to members of that team.

In our pilot research, students worked in teams to develop hypotheses regarding one of three strands of illness in River City (water-borne, air-borne, and insect-borne). These three disease strands are integrated with historical, social and geographical content to allow students to experience the realities of disentangling multi-causal problems embedded within a complex environment. At the end of the project, students compared their research with other teams of students to delineate the many potential hypotheses and avenues of investigation to explore.

Findings

In our first pilot implementation of River City, using two public school classrooms in Boston, MA, we examined usability, student motivation, student learning, and classroom implementation issues (Dede & Ketelhut, 2003). One sixth- and one seventh-grade classroom in different schools with high percentages of ESL students implemented the River City curriculum; control classrooms used a similar curriculum delivered via paper-based materials rather than technology. This implementation was followed, after much design work, with a focus group, a pilot in an informal after-school program, and a more formal implementation in a lab school in California. All three of those implementations involved a similar target student body, but lacked a control group, as our emphasis was more on formatively understanding the strengths and limits of the current design. The results of those implementations are still being studied.

We collected both qualitative and quantitative data from students and teachers over the three-week implementation period. Both the Patterns for Adaptive Learning Survey (Midgley et al, 2000) and a content test were administered to students, pre- and post-intervention. In addition, demographic data and teachers' expectations of students' successes were collected. Teachers in the initial pilot responded to a pre- and post-questionnaire regarding their methods and comfort with technology. The experimental intervention classroom teachers also wrote a narrative at the end of the project about their perceptions of the MUVE. Across all implementations, students found the MUVE interface readily usable and the learning experiences motivating, even after repeated exposures.

Preliminary results indicated the MUVE is motivating for all students, including lower ability students typically uninterested in classroom activities. More detailed results on the initial controlled implementation have been previously reported (Dede & Ketelhut, 2003). This report will concentrate on illuminating the effects of the MUVE on girls, racial minorities, students identified as ESL, and low SES students as identified by free or reduced lunch status.

In our initial controlled pilot study, we found that six out of seven experimental students scoring less than 35% on the content pre-test improved their content knowledge above that level, while only two of five control students did so. If we extend our investigation to those students scoring 11 points or less on the content pretest out of a possible 30 points, we find that 10 of 11 students improved their content knowledge an average of 63% over the course of this implementation (one student's score went from 10 down to 6).

Who were these students? Prior to the start of the study, we asked the two teachers to rate their students' probable success in the project. These 10 students' ratings ranged from 2 to 4 on a scale of 5, averaging 2.8, below average. Six of these students were female, all were of color, all were low SES by our definition, and 4 of the 10 were ESL.

Gender

Throughout our analysis of the initial pilot study, gender consistently was not a significant predictor of success in this project. The lack of differences between boys and girls in our study echoes the findings of Bruckman (2000) in her study of learning in the *MOOsE Crossing* virtual environment. Bruckman performed a portfolio-style assessment of 50 children using *MOOse Crossing* to study programming. Although Bruckman conducted a careful study of any systematic differences in learning between boys and girls in MOOse Crossing, her data showed gender to have no relationship with students' level of involvement or achievement.

In examining our 11 lowest performing students, however, we found that over half of them were female which supports the previously cited research on the increasingly negative attitudes and performance of girls towards science starting at this age. Focusing on these 6 girls shows an interesting effect of the MUVE. The science self-efficacy of this group, the belief that they could successfully do science, increased 7% over the 2 week implementation. While a smaller effect, their motivation also increased.

Three girls from the 7th grade experimental classroom, one of whom was in our lowest-performing group, offer a case in point. These girls were intrigued with our initial presence in the classroom, but--by the time the pre-testing was concluded--they had reverted to their previous inattentive behaviors. In fact, for the first day or two of the intervention, they groaned when we entered the room. Two weeks later, these girls were still inattentive to their teacher, but instead of passing notes on non-academic issues, they were working hard on finishing the project, and demanded that I read their final report immediately. As a group, they raised their science self-efficacy by 20%! While anecdotal, this example was not solitary and potentially indicates a role for MUVEs in the classroom.

Race and Class

Our initial target audiences are inner-city schools; and, as a result, we have so far implemented River City primarily with minority populations. No comparison data with upper class, suburban or White populations is available at this point. We found in our first pilot that River City was motivating for lower SES students and particularly for Hispanic students, especially those who appear to be metacognitively aware of the inquiry process in science. Hispanic students with low GPA and low SES improved their content score by approximately 20 points across the board! Of additional interest was the fact that Hispanic students, regardless of native language, scored better then non-Hispanic students by nearly 5 points. This relationship, however, changes depending on students' initial metacognitive awareness of the inquiry process. This potentially indicates that there are students whose GPA is not reflecting their metacognitive awareness of inquiry, and possibly this MUVE has allowed these students to grow.

Looking at our lowest achieving group of 11, all qualified for free or reduced lunch (low SES, therefore, by our definition), 2 classified themselves as Hispanic, 6 as African-American, 2 as Asian and 1 as Cape Verdean. As stated earlier, this group as a whole improved their content knowledge by 63%, their self-efficacy went up by a small amount, and their motivation basically remained the same. This last is significant because it matches what we saw from the experimental group as a whole and compares favorably with the decrease in motivation seen for the control group.

DISCUSSION

Despite a major emphasis on learning how to design MUVEs for learning, we were able to make several discoveries about their potential in the classroom. MUVEs appear to be motivating and to improve academic self-efficacy. In addition, MUVEs seem to have a greater impact on learning for the bottom third of students. We found in our studies that girls and minorities both found success in River City. Of even more interest, given the increasing negative student attitudes towards science seen over time by Farenga (1998) and Clark (1999), girls and minorities enjoyed River City and increased their science self-efficacy.

What factors might account for this? In our design of River City, we intentionally created a lead female figure to model science success for girls. This model, Ellen Swallow Richards, was the first woman to earn a chemistry degree at MIT (at a time when that institution found it necessary to have separate science laboratories for women); she potentially combats stereotypes internalized by young woman. We intend to test hypotheses about gender-related mentoring in future implementations of River City.

Another intentional design element revolves around identity. In River City, students are allowed to choose their own name and avatar, allowing students, if they choose, to try on a different identity from the one they use in school. Turkle (1997) and Murray (1997) document a variety of studies indicating that identity play in multi-user virtual environments is an important form of expression for many participants, especially adolescents. We discovered the importance of choosing identity when debriefing students in our California implementation. When students were asked to make recommendations about improving our curriculum, some anecdotal differences by gender did appear. The students taking part in the River City implementation had recently completed a learning unit utilizing the "Whyville" software environment (www.whyville.net). In Whyville, students can perform tasks to earn 'money'. This money can be used to purchase new graphical elements used to individualize the appearance of a given student's avatar. While a number of students of both genders mentioned their desire for River City to contain money-earning tasks and purchasable goods, more girls than boys focused on the ability to purchase avatar customization components such as clothes, hair, and facial features. Whyville has a higher population of regularly participating girls than do traditional online educational environments; these customization capabilities may be one reason for that. While River City does not have the depth of customization that Whyville does, it potentially includes enough to appeal to girls.

We also intentionally created a design intended to involve diverse students from lower socioeconomic backgrounds. The tenement area of River City is a key region in terms of factors related to disease. Its conditions may evoke in immigrant students, members of minority groups, and lower SES pupils feelings about contexts in which they have lived or live now, or where people reside to whom they are emotionally close. This provides an opportunity for students to relate ideas and findings in the unit to situations that may be familiar in their lives and that have meaning in their culture.

Overall, these findings encourage further refinement and experimentation with curricular MUVEs as a learning modality that can help teachers reach students struggling with motivation, self-worth, and lack of content knowledge. These data are promising, but not conclusive about the curriculum's educational value or the effectiveness of MUVEs for learning. We are continuing to improve our curriculum via a design-based research strategy (The Design-based Research Collective, 2003; Dede, 2004), using observations and interviews with an iterative cycle of focus group participants. We are centering our improvements on creating various avenues for student investigation that fit different learning styles (e.g., collecting data via interviewing agents vs. analyzing water samples vs. observing tacit visual clues about possible sources of disease). In a typical middle-school classroom faced with a diverse set of learning styles, the teacher must alternate pedagogical strategies to aid each of these. Even under the best of circumstances, in whole class instruction at any single moment some students' learning styles block them from understanding the lesson. In a MUVE, students can individualize their learning based on their own styles. We hypothesize this allows different groups of students to all find success.

CONCLUSION

Because MUVE research is in its infancy, and because we are still evolving curriculum and articulating insights about MUVE-based situated learning in the crucible of practice, we are using a design-based research (DBR) approach in our study. In each iteration of our study, quantitative data are revealing findings about the relative effectiveness of River City for different subpopulations of students, and qualitative data are providing insights about the reasons underlying those comparative differences.

An example of a change we have implemented as a result of this design-based research strategy is increasing the number of tacit clues embedded in the learning environment to ensure that high academic achievement students find continued interactions with the curricular unit challenging and interesting. While we are seeing success with those who are low achieving, we want to ensure high achieving students maintain their motivation and have opportunities for advanced learning.

An important emphasis in our research is assisting students across the spectrum of academic achievement gain in motivation, self-efficacy, and science knowledge and skills. In particular, educators need help in engaging and teaching subpopulations of learners with special needs, students unmotivated by standard instructional approaches, and pupils with learning styles more visual and kinesthetic than symbolic and auditory. Our environment/curriculum is targeted specifically to narrowing the gaps among students by helping all learners reach their full potential via methods particularly applicable to students who are currently underperforming because of how they are taught in conventional classroom settings. Our quantitative studies, including the use of a control curriculum, are helping us determine whether the leverage for learning and engagement provided by our work are substantial enough to merit moving to large-scale experimental research on implementation.

FIGURES

Figure 1: Talking with an Agent

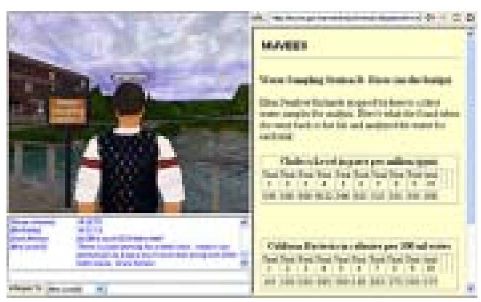

Figure 2: Collecting Water Quality Data

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