Using a Simulation-Based Learning Environment to Enhance Learning and Instruction in a Middle School Science Classroom

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The goal of this project was to help science teachers shift to a more inquiry-based teaching style by supplying learning tools that support a more student-centered approach. The project employed PSI (Personal Study Instrument) Sim Modules, a simulation-based electronic learning environment designed to address misconceptions in middle school science. Our findings indicate that using such tools will encourage teachers to engage in critical reflection about pedagogical content knowledge which can have a transformative effect on their teaching.

For the past two decades, instructional technologists have been projecting that real-world simulations would have a great impact on education (Thomas & Hooper, 1991; Dede, 1992; Hardin & Ziebarth, 2000). Although one may find a number of simulations online and elsewhere, they have yet to be fully embraced in modern classrooms. There are many reasons for this, including the variability in the quality of online resources, the lack of highly targeted resources, and the shortage of teacher preparation time. However, there is a larger issue that looms in the classroom that may have a greater
impact on learning: simulations are squarely in the intersection between educational change and technological development. In other words, in order to use simulations effectively, teachers not only have to learn the technology, but must also change the way they teach. Although simulations can be demonstrated as part of a directed learning activity, they work best when students are in inquiry mode, interacting with the simulation themselves. Like science experiments, simulations (and many other computer activities), work best when students are functioning in a hands-on modality (de Jong et al., 1998; DeCorte, 1990). Currently few teachers are conducting their classrooms in a student-centered manner, and in addition, a low percentage of teachers even feel comfortable managing a student-centered classroom activity (Kain, 2003; King, 2003). Yet, learner-centered activities are a large part of what most people do in their chosen professions.

GOALS

The goal of this project was to help science teachers shift to a more inquiry-based teaching style by supplying learning tools for their students that support a more student-centered approach. In addition, we hoped to help students develop a greater understanding of, and interest in the science, technology, engineering, and mathematics (STEM) content areas. The project employed Personal Study Instrument (PSI) Sim Modules, a simulation-based electronic learning environment designed for individual use. Each PSI Sim module is an electronic learning environment (ELE), a web-based piece of software that provides the learner with a video-based challenge, background information in the form of an electronic slide show called "field notes," a methodology section that contains a laboratory exercise sheet, and a simulated laboratory experience. In PSI Sims students collect data and report their findings much the way they would in an inquiry based science experiment. Each module is mapped to state and national science education standards (NSES). The learning goals of the modules are to help students:

- Develop deeper and more personal ways of thinking about science.
- Engage in interactive, inquiry-based methods of learning about science.
- Obtain a greater understanding of science content.
- Address misconceptions they may have regarding science.
PURPOSE

In the modern world learning, interacting and managing are no longer separate activities. Hodgins (2002) defined "Learnativity" as the convergence of learning, working, capturing and managing knowledge and concept formation in local, global, and virtual communities. The computer and the communication tools associated with it have changed not only the way we work, but the way our tools work as well. For example, modern labs test pesticides in fruit using robotic arms, display monitors, and computers that deliver comprehensive reports on the elements found on the fruit. In school science labs, however, we still require students to learn to scrape peaches into a petri dish to test for insecticides. In such cases, the implementation of simulations in the classroom would be closer to reality than the experiments currently being used.

It is clear that we need to better understand how to shape our curriculum around our rapidly changing reality. In order to do this, we need to understand how to best utilize the technological tools and pedagogical strategies available to educators and educational institutions. Although every course, and perhaps every classroom represents an environment for developing such understanding, we have no systematic way to discuss change and no context for thinking about it. Teachers are simply not well versed in how to apply and when to apply alternate approaches in the classroom (Bencze & Hodson, 1999).

In designing lesson plans, most teachers consider only directed modes of instruction, and there may good reason for this. For example, Carse (2000) has suggested that educational experts are influenced more by ideology than by rigorous research findings. Could it be that the plethora of (often weak) educational research has fractalized our understanding to such an extent that the traditional paradigm of direct instruction is simply embraced?

Although direct instruction methods have been and continue to be favored by many educators (Carnine, 2000; Schug, Tarver, & Western, 2001), critics (Hannafin & Land, 1997; Brown, Collins, & Duguid, 1989) claim that many real-world skills such as critical thinking and practical problem solving are not emphasized enough through direct instruction. Further, although direct instruction can be effective, it can have negative side effects including the promotion of "scripted teaching." The belief that alternate methods of instruction might prove to be superior to direct instruction is widely held by constructivists and consequently many research studies have studied, or attempted to develop new modes of instruction (Lave & Wenger, 1991;
Brooks & Brooks, 1999). In other words, researchers have often examined model after model in search of something better than direct instruction, rather than trying to determine appropriate teaching modalities and exactly when they should be applied.

If there are indeed appropriate teaching models and proper times to apply them, it should be possible to encourage teachers to incorporate them into their teaching. Unfortunately, an analysis of past efforts promoting a shift towards alternate teaching styles is not encouraging. In the field of science for example, the use of hands-on experiments has been promoted for several decades. Still, in a review of science education reform initiatives Levy and Century (2002) concluded after more than 100 years of reforms—all of which turned away from traditional methods, most science is still taught using traditional texts with traditional methods. This observation notwithstanding, the researchers found reasons for sustained commitment to hands-on science in the nine districts they examined, and these reasons were related to a shared system of beliefs about the importance and value of teaching science.

Most teachers and educational practitioners are not as concerned with teaching ideologies and theoretical constructs as they are with what works. Further, most teaching, including some distance teaching, is still done at the same-time in the same place. Questions persist: How can we prepare teachers to employ new technologies in their classes? How can we encourage teachers to discover and apply appropriate pedagogical methods? How can these things be done within a "doable" framework?

To begin to seek answers to these questions we worked with two middle school science teachers on the implementation of a simulation-based electronic learning environment (ELE) in their classroom. Supported by a small provost initiative grant from Ball State University, we implemented the PSI Sims ELE into ten 7th and 8th grade science classrooms in Indiana. Two teacher participants and approximately 250 students used the modules. Prior to implementation the modules were synchronized with classroom texts, national science standards, and Indiana state standards.

SIGNIFICANCE

The SCANS report (U.S. Department of Labor, 1991) argued that while the world has changed and work is changing most schools have not changed fast enough or moved far enough to integrate sophisticated learning tools into the curriculum. Furthermore, according to a recent CDW Corpora-
tion study called Teachers Talk Tech (Crystal & La Vanway, 2005), teachers are more likely to use technology to ease administrative requirements than to use it for instruction. In the survey, 85% of teachers said they were adequately trained in Internet, word processing, e-mail, but 27% say they have little or no training with integrating computers into lessons. The use of technology in the classroom, in this case the use of a simulation based ELE, requires a new kind of pedagogical-content knowledge (Shulman, 1987) that is more student-centered than traditional direct instruction.

In the 2005 report: Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, the National Academy of Sciences identified an alarming statistic: a gradual decline in performance and interest in science and mathematics as U.S. students get older. Fourth grade students perform as well in science and math as their peers in other countries, but 12th graders in 1999 were almost last among all students studied. As a result, there is increased focus on STEM instruction in K-12 schools across the country. In addition, recent changes in science education have called for teachers to engage students in more authentic scientific practice in education. The new science curriculum puts greater emphasis on the nature of scientific inquiry and the complex relationships among science, technology, society and environment.

There is much evidence that academic programs, and science programs specifically, must go beyond the textbook to accomplish their goals. In 2000, Project 2061, a science, mathematics, and technology reform initiative, released findings from its evaluation of K-12 science textbooks, which concluded that most science textbooks cover too many topics that are not fully developed and include activities that either are irrelevant to learning key science ideas or do not help students relate what they are doing to the underlying ideas (American Association for the Advancement of Science, 2000).

BACKGROUND

The PSI Sim Learning Environment was produced by The Athena-Group, a Gainesville, Florida company. Working under a grant from the National Institutes of Health, Athena-Group researchers had originally developed the Lord Kelvin Learning Environment: a robust computer centric learning environment (Figure 1). Lord Kelvin contained a “controller” so students could control their own instruction. Much of the information presented to students was text-based. The controller contained buttons for each lesson component and clicking a button often evoked a new button set. The
Lord Kelvin Learning Environment was tested in several schools across the United States. While students appeared to enjoy working with Lord Kelvin, teachers seemed somewhat overwhelmed with all of the information contained in each module and as a result they thought that they would not be able to "fit the modules into their schedule." Based on this feedback, Athena researchers refined and simplified the modules to produce the PSI Sim Electronic Learning Environment (Figure 2). The PSI Sim Learning Environment was designed to optimize student performance, allowing the students to complete each activity in one 50-minute class period. The interface provides a consistent, predictable system to manage multiple sources and channels of information and experiences for students and teachers. Much of the information included in the original Lord Kelvin modules was employed in the creation of the PSI Sim Teacher Resources (http://www.athenaed.com/psisims/).

![Figure 1. A screen capture of the Lord Kelvin learning environment](image)

**PSI SIM DESIGN**

A typical PSI Sim learning module includes background material, content information, process information, video "how to" tutorials, and a virtual
simulation that allows the student to engage in a science investigation. Each module introduces a concept with a challenge, provides methodology information and lab materials, and contains video-based simulation walkthroughs to help students understand the virtual setting. Finally, the student engages in a photo-realistic virtual experiment—building hypotheses, manipulating experimental variables, and collecting and analyzing data to test their hypotheses.

![The Insulation Experiment](image)

**Figure 2.** A screen capture of the PSI Sim electronic learning environment

It was our hope that as students interacted with the ELE they would be encouraged to make predictions about possible solutions to the problems they encountered and would then test their predictions through further experimentation and interaction. Many of the modules contain a graphing function that plots points as the experiment proceeds. By manipulating variables, and observing the changes that occur students can begin to understand processes and relationships. These simulated activities model the scientific process. Because the ELE does not provide answers to questions or problems, teachers can use it to pose “what if” type questions that students can
investigate on their own. In addition, students can use the ELE to address misconceptions they have about the content.

Implementation

The project was implemented in a rural middle school located in East Central Indiana. The participating school serves approximately 671 students in grades 6th–8th, employing approximately 32 teachers and other education professionals. The school is located in a rural section of the state and is comprised of a student population of 89% white, 6% black, and 4% other ethnicity. In the 2005-06 academic year the school’s Indiana Statewide Testing for Educational Progress (ISTEP) average surpassed that of the state average.

The first step was to meet with the Principal and the teachers to develop a funding and implementation plan. Once the participants were identified discussions revolved around the logistics of implementation including:

- curricular connections;
- standards;
- technology availability; and
- professional development.

Discussions of these topics provided information on the funding necessary for implementation. During our initial meeting we learned that the study could be conducted at minimal expense. For example, the schools had two computer labs available for the teachers’ use on the days that the ELE modules would be implemented. The modules were found to be compatible to the science textbook used in the middle school science curriculum and were well connected to the Indiana science standards. Because ease of use was built into the ELE and extensive usability tests were conducted on them prior to this study teacher training on the ELE was minimal and could be completed in an afternoon.

Funding for the project was secured and we immediately began the implementation phase of the project. Our budget allowed for the purchase of 30 copies of three PSI Sims modules and accompanying teacher training. The teachers requested the following modules based on their curricular compatibility:

- Electric Potato: This simulation module explores whether a potato or a lemon can be used as a battery.
- Chemical Mixer: In this simulation module chemicals are mixed like music is mixed to understand proportionality in molecular composition.
• Code Breaker experiment: In this simulation module students code and decode binary messages against a backdrop of the history of communication.

Perhaps the most crucial element of any technological implementation is the availability of technical support. The school was found to have a rich amount of technical support available to ensure that integration was as seamless as possible. A technician would be available to us and a time line for implementation was set:

• May 12 software installation
• May 12 teacher training
• May 13 ELE implementation
• May 13 teacher feedback session
• May 16 ELE implementation
• May 16 teacher feedback session

Of course any implementation of an innovation is often met with unexpected challenges and our implementation was no exception. Upon arriving at the school on the day of installation we learned that the technician no longer worked for the school corporation and none of his staff were familiar with our project. Fortunately, however, the two technology support staff were un daunted by the task at hand and willingly loaded the ELE onto the school’s network, tested the computers in the lab to be certain they had JAVA and Quicktime™, and tested the menu from which the modules were accessible (Figure 3). The next day the ELE worked perfectly from the school’s network and students were able to access the ELE by a simple click of the mouse.

Figure 3. The PSI Sim main menu from which users can access the modules
PARTICIPANTS

The participants included 250 seven and eighth grade science students and two teachers from a rural community bordering a major urban center in the Midwestern United States. Forty-six percent (46%) of these students participated in the pre and posttest exercise for the Chemical Mixer (n=116), and 36% (n=89) of the students participated in the pre and posttest for the Electric Potato. Only the 8th grade students participated in the pre and posttests. The sessions were part of the students’ class time, and the teachers and the researchers were present during the session to answer questions and observe. Data were collected in the spring.

DATA SOURCES

Data for this study were collected from three data sources: teacher interviews, student and teacher observation, and test scores. Prior to implementation, teachers were interviewed to determine their preferred teaching modality. In addition, after the implementation teachers were again interviewed to determine if changes in their thinking and/or teaching had occurred.

The second data source was the observations made by the researchers. During the implementation of the three modules the researchers observed both the students’ interactions with the ELE and the informal question and answer sessions after the modules were completed.

The third data source was the pre and posttest scores of the 8th grade students. The first week, 116 students completed a 15-question pretest pertaining to the scientific content addressed by the ELE Chemical Mixer module that would be used in their classroom. Students then began to use the ELE and the integrated simulation. In each session, each student had his or her own computer with the simulation accessible from the network. After completing the module, which took approximately 40 minutes, the students were given a parallel form posttest. Simultaneously 7th grade students were using the Code Breaker Experiment in their science classes however; these students did not participate in the pre or post testing. The following week the Electric Potato Simulation was implemented in the 8th grade classroom and again a pre and posttest was administered to students this time with 89 students participating. The 15-question test addressed topics such as circuits, charge, and voltage. After completing the posttest the teacher spent the remainder of the class in an informal unstructured discussion of the module with the students to learn their reactions and to further gauge their understanding of the concepts.
EVALUATION

Our approach to analysis combines qualitative and quantitative approaches, reflecting the broad range of data used to inform our evaluation of the project activities. Standard statistical methods were employed to student pre and posttest data to compare learning gains both within and across modules and gender. Qualitative data from teacher interviews and classroom observations were analyzed using constant comparative analysis (Miles & Huberman, 1984) for data reduction and the development of descriptive categories. It is important to note that internal validity is increased through the triangulation of these various data sources (Lincoln & Guba, 1985).

RESULTS

Table 1 presents the mean, standard deviations, and gain scores for all classes participating in the study. The average gain score for the Chemical Mixer was 1, while the average gain score for the Electric Potato Experiment was 2.75. A distinction between the two experiments relates to the length of the video notes provided in the learning environment, the Chemical Mixer had much longer video segments and teachers reported that some students lost interest in this passive medium and went ahead to the simulation.

Figures 4 and 5 present the pre and posttest scores for the Chemical Mixer and the Electric Potato. The posttest scores for the Chemical Mixer increased for both the male and female participants. Also notable are the pre and post test averages for each gender. The achievement gap between genders is also of interest as males on both experiments scored higher than did the females on both the pre and post tests.

<table>
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<th>Table 1</th>
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Table 1 Continued

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<th>Period 6 Post</th>
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<td>Mean</td>
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Figure 4. Chemical mixer pretest posttest scores

Figure 5. Electric Potato pretest posttest scores
TEACHER FEEDBACK

In addition to the numerical increases in means, we are encouraged by the observational and anecdotal data that were recorded. At the conclusion of the experiment the researchers met with the classroom teachers and students. The teacher’s responses pertaining to the implementation of the project into their science classes were encouraging. Also encouraging were the teacher’s eagerness to use the simulations again the following academic year with new students. When asked how successful they felt the experience was the teachers responded positively:

It was great—the kids enjoyed using them, they are very engaging. The students like to get in and play with it and when things don’t work the way they should they have to slow down, go back and review the methodology. In fact, during study hall my students asked if they could do them again and if there were more they could use.

It was great because it [ELE] enabled the students to get a “hands-on” experience with something that they may not be able to get a hands-on experience with otherwise and it has driven home some of the concepts and ideas that they need to know.

We are really lucky because we have it [ELE] on our intranet so students can access it anywhere in the school. We have had students go home and try to access it because they think it’s online and they are really surprised when they can’t access it because they want to go home and do some more of it.

In fact, the learning was extended beyond the use of the ELE and the teachable moments sometimes occurred after students completed the module and left the computer lab as referenced by this comment:

It was interesting because during our class discussions there seemed to be some ah ha moments when the students said “I understand—better”
TEACHING MODALITIES

Prior to the implementation of the PSI Sims the teachers described their teaching practice as student centered and inquiry based while at the same time suggesting that their students were generally accustomed to a more teacher centered classroom as evidenced by the comments below:

Our students are more used to directed instruction they kept wanting me to tell them what to do...I have one group in particular that is not as advanced as the others and they really want me to give them step by step instruction on how to complete the experiment. I thought that maybe the instructions were not that good, but then I went through the methodology myself and realized that yes these are really good instructions and they tell the students exactly what they need to know. But this has helped students learn that it is okay to learn on your own and it definitely helps them become more self-learners. It also gives them the idea of an inquiry based science lab where maybe there is not always the canned answer for everything they can actually explore and learn things that they may not know they were going to learn.

The students are used to sitting quietly in rows. In fact, sometimes it is a challenge to get them to take ownership in their learning and to go that extra step, but the ELE modules make it really easy because they have the headphones on and it even makes it a little safer [for the students] to experience those things. I think the students have begun to enjoy this type of learning, but I don’t think that I have changed the way I teach.

During the study it became evident that when teachers switched teaching modalities some students had difficulty adjusting to this new format. As a result of the findings of this study we learned that we cannot assume that students will readily embrace a classroom that is not centered on direct instruction. This is supported by the findings of Hirsch (1998) who cited several studies in which a significant number of students were more receptive to traditional methods of teaching. His interpretation of student receptivity warned that teaching to students' comfort levels has become so much the norm that students expect it (Hirsch, as cited in Kain, 2005).
One note worthy aspect of the study related to the student's preference for interactive media over other forms such as video. Although video and animated instructions provide background information in the form of field notes, examples on how to do the simulation, and how to collect and record data, students appeared to move hastily through these sections to get to the interactivity. While we would expect students to lose interest in text we were surprised they so quickly lost interest in other forms of media (i.e., video and graphics). In fact, students were seen multi-tasking when listening to passive media in the form of video. For example, one student counted the change in the bottom of her purse while watching the video instructions while other students simply skipped the video methodology sections all together. Not surprisingly these students were unable to complete the experiment. The teachers recognized this problem and commented:

Some students were tempted to skip over the methodology portion to quickly get to the simulations themselves, and I have had to do some things to slow them down like provide them questions that go along with the methodology section. I mean there is so much information in those sections and it's good stuff, I mean if the kids would listen to it they would learn so much! For example on the Chemical Mixer they talk about the various forms that the periodic table has gone through and it is so interesting even for me as an adult to think about what happens with the periodic table and how it could be changed to maybe even make it better so I try to slow them down a little bit with some directed reading is a good thing for me to do.

The fact that students appear more interested in interactive components of the modules is not surprising, but there were indications that students did not view passively watching an instructional video as particularly instructive. There is reason to believe that these students multi-task more than adults and perhaps passive media does not help them focus their attention and this may warrant further study. The teachers pointed out that as the students interacted with the ELE and learned that it would be difficult (impossible) to complete the experiment without completing the methodology section, students were more inclined to watch the videos. We asked the teachers: "Do you think that the more often your students use these simulations the more likely they will understand the importance of going through the methodology section and the simulation walkthrough in order to understand how to do the experiment?" Their response was: "We saw that with the second group a little bit more that they watched the methodology but they still thought it was really boring."
In fact, the teachers provided the researchers with comments they believed would enhance the overall quality of the ELE. For example, one teacher pointed out: “The information section was long in one of the modules and the kids had a hard time keeping their interest in the video instructions. It might help if there was a notes section where students could take notes during this session.”

As a result of this feedback a notes section has been added to the ELE.

Finally, we asked the teachers to talk about the drawbacks they encountered with the ELE implementation. Even though this school had a seamless implementation due to outstanding tech support and the availability of computers, the teachers pointed out that each year more teachers want to use the computer labs, which makes it more difficult to schedule time in a computer lab. “In fact, next year we will only have one computer lab so the lack of available computers makes it difficult. It’s hard to fit them [ELE] in, not because the ELE doesn’t fit well with our curriculum, but because we can’t get time in the computer lab.”

The posttest results and teacher observations, as well as our own observations encourage us to continue to explore ways in which we can support teachers in the creation of learner-centered classroom activities particularly through the use of a simulation based ELE. We are ever aware, however, of Hirsch’s (1998) cautions, that we, like the teachers in this study, may have to “teach” students the value of this type of classroom.

SUGGESTIONS FOR FUTURE PRACTICE

In this project, we were interested in discovering methods that help teachers become more student centered. Our strategy was to provide teachers self-contained modules that would give them a forum to do just that. The study indicates that teachers will engage in critical reflection about their teaching when using such tools and we believe that continued use will help transform their teaching. Further, we believe that simulation based learning modules have great potential in the middle school setting and that dramatic increases in learning and interest in science are quite possible. As the teachers pointed out “Every time we used the ELE, when analyzing my results I have always come up with statistical significance, there has been some gain from them [students] using the ELE.”
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References


