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Creating Epistemologically-Rich Learning Environments: Computer Modeling Tools for Pre-Service Elementary and Middle School Science Teachers

C. Schwarz, J. Meyer, & A. Sharma, MSU

Abstract

In this project, we studied elementary and middle school pre-service teacher’s use of computer modeling tools to determine how those tools impacted their views of technology, their understanding of scientific epistemology, and their learning of science pedagogy. These student teachers from an undergraduate elementary science methods course at a large university in the Midwest used several computer-modeling tools throughout the semester for their own science learning and teaching. Analysis of classroom conversations, student work, and interviews indicates that student teachers’ use of computer-based modeling tools expanded their understanding of the types of software available for science teaching. However, the intervention made only modest impact on student teachers’ perceptions of the usefulness of computer modeling tools for enabling learners to develop and refine their scientific theories.

Summary

Objective

The objective of this paper is to present results from a semester-long study with pre-service teachers in an elementary science methods class in which we investigated the effects of using computer modeling tools on the student teachers’ views of technology, their understanding of scientific epistemology, and their learning of science pedagogy.

Why engage student teachers in learning about and using computer modeling tools in an elementary science methods course? Computer modeling and simulation software has revolutionized science and engineering, enabling scientists and engineers to engage in new kinds of experimentation, analysis, and theory building never before possible (Morgan & Morrison, 1999). Computer models¹ have also shown great promise for facilitating a corresponding revolution in science education, enabling students and teachers to visualize and develop reasoning about abstract scientific concepts and phenomena, access cutting-edge scientific research, engage in authentic practices of science, and do so in interesting ways. (Feurzeig, 1994; Feurzeig & Roberts, 1999; Gilbert, 1991; Lehrer & Schauble, 2000; Mellar, Bliss, Boohan, Ogborn, & Tompsett, 1994; Passmore, & Stewart, 2002; Raghavan & Glaser, 1995; Schwarz & White, 2002; Spitalnik, Krajcik, & Soloway, 1999; White & Frederiksen, 1998).

¹ A computer model is a piece of software that represents phenomena in a way that can help predict or explain those phenomena. Often, the software will step through time sometimes showing a visual representation of abstract components, causal relationships, or ramifications of data or relationships.
Prior research indicates that teachers know little about the process of scientific modeling (Justi & Gilbert, 2002; vanDriel & Verloop, 1999; vaDriel & Verloop, 2002) – the core of what theory building in science is all about – and few teachers engage their students in using computer simulations and models for science learning (Becker, Ravitz, & Wong, 1999). Elementary and middle school teachers are at an even greater disadvantage having less content knowledge and background in science. Such challenges are due in part to teacher’s limited exposure to scientific modeling, limited software availability (particularly at the elementary level), and lack of software accessibility.

In order for elementary and middle school students to understand modeling as a core component of scientific literacy, and to become increasingly technologically literate, their teachers must understand more about scientific modeling and how to use modeling and simulation software in a meaningful way.

As a result, we created an intervention in the an elementary science methods course to enable student teachers to learn about and use computer-modeling tools, as well as incorporate them into their science teaching. A primary goal of the intervention was to help the student teachers learn about modeling as a way of thinking about the nature of science and as a pedagogical method. A secondary goal of the intervention was to help the student teachers learn about capabilities and limitations of several kinds of computer software.

**Theoretical Framework**

This research concurs with prior work suggesting that scientific modeling can play a central role in enhancing the learning of science (Feurzeig & Robers, 1999; Mellar et al., 1994), and that learner’s epistemic knowledge is important to address and to align with the purposes and processes of science (Carey & Smith, 1993). Further, we acknowledge and build off the research that investigates teacher content knowledge and pedagogical content knowledge about scientific modeling (Cullin & Crawford, 2003; Justi & Gilbert, 2002; vanDriel & Verloop, 2002).

Our framework aims to help student teachers develop a modeling perspective in understanding both scientific epistemology and pedagogy. By ‘modeling perspective,’ we mean a perspective in which science and engaging in science is seen as a process of understanding and creating scientific models through revision, reflection, application, and argumentation. The focus of such an approach is both on the processes of science and the habits of mind that operate in that community using the tools and practices of the scientific community.

**Methods**

This study incorporated a semester-long intervention with twenty-five undergraduate pre-service teachers in an elementary science methods course during the fall of 2002. Students from the course were predominantly seniors from a large Midwestern state university.

The intervention consisted of four core components. First, the instructor introduced the notion of scientific modeling and maintained this theme throughout the course. Students then used computer models and constructed physical models in their own science content explorations.
about solar motion and light. Specifically, the class used the simulation software “Starry Night”, and Riverdeep’s “Laser Light Lab” while constructing physical models to explain both how the sun moves in the sky and how light travels. Third, one group of six students was able to incorporate a piece of simulation software into their second grade lessons on the weather and fabric. (Student teachers had to teach three lessons during the semester in their elementary placement classrooms.) Unfortunately, we were able to identify no other appropriate pieces of software to use in the other units that included the kindergarten unit on fabric, the first grade unit on what makes objects living/non-living, and the third grade unit on the water cycle.

Finally, students spent portions of the last three weeks of the class exploring a website our project created that included a web page on “Why modeling and simulation tools?” and ten other pages that included links and evaluations of commercially and research-produced pieces of simulation or modeling software. The evaluations were written by our research team, and included benefits and drawbacks of using the software for teaching, their affordances for science instruction, etc. After studying the website, student teachers chose one of five pieces of research-oriented computer modeling software to study in depth. Software included ThinkerTools (force-and-motion) (White & Frederiksen, 1998), Model-it (relation-based) (Spitulnik et al., 1999), Archimedes & Beyond (matter) (Smith, Snir, & Raz, 2002), Models of Matter (matter) (Smith, Snir, & Grosslight, 1992), or MARS (matter) (Raghavan & Glaser, 1995). Students worked in pairs to evaluate the software and to create a small lesson plan using the software. Finally, they taught each other about the software they studied.

Data Sources

In order to evaluate the effect of such an intervention on student teachers’ views, we collected five sources of data. First, student teachers took a written pre/post test that included twelve questions asking them about their understanding of technology, their views about teaching and the nature of science, and their understanding of modeling. Questions ranged from “List three or four ways you might use computer software in your elementary science teaching” to “How do you think science can best be described?” to “How do you think computer models and scientific models can be useful for scientists, for teachers, and for learners?” Secondly, we collected journal entries that related to students’ thinking about technology and we videotaped classes in which students talked about or used models and modeling tools (approximately six classes out of fifteen). We also collected student teachers’ final software evaluations and lesson plans. Finally, we interviewed eleven student teachers after the end of the semester about their experience using the software, and their understanding of the nature of science and scientific modeling, among other aspects.

Results

Analysis of the data sources indicates that the intervention had a modest impact on student teachers’ view of technology, their understanding of science epistemology, and their thinking about science pedagogy. Data from the pre/post test shows significant change in roughly a third of the written responses.
With respect to student teacher’s views about the technology, our data indicates that the intervention clearly expanded student teachers’ understanding of the kind of software available for teaching. For example, one student stated, “The [software from class] helped me see the different types of software that are available and I wouldn’t have had a clue about. Now I feel like I have a better understanding of what to look for. If I did decide to use software in my classroom, I would know not to just go look for an educational game. I’ll look for things that actually teach something or will really be beneficial.” Nonetheless, we also found that many student teachers still based much of their final software evaluations on criteria of engagement and aesthetics (such as software graphics) rather than software capabilities. We found this result supported in the interview where one student stated, “Aside from [age-appropriateness], I would have to look for the aesthetics desirability of the software, the ease of use, the concepts that the software is trying to convey. I mean you would have to take a lot into consideration.”

With respect to teacher’s understanding of science epistemology and pedagogy, we found that the significant epistemological and pedagogical questions raised during the students’ experiences and in class discussions mildly impacted student teachers’ understanding. On the one hand, we found that some students learned aspects about what modeling entails (e.g. modeling can be a process of embodying key aspects of a theory into a model, running that model, testing that model, and revising that model). In the final interview, for example, one student stated that “Modeling is a way of showing something. I mean you can put it on paper or make a model like [on the] computer then you can change the different variables and study the results.” On the other hand, no students obtained a modeling perspective or one in which they regarded science as a process of model-building and revision within a practicing scientific community. For example, when one student was asked, how is science similar to model-building? She responded, “I don’t know. I guess it is very similar. I don’t know. I have no idea. I know there is a correlation there, but I really don’t know how.”

Perhaps most significantly, at the end of the course, students primarily saw the purpose of the software as providing simulations that present students with the correct scientific answers rather than as providing tools that can help students externalize, compare, and discuss their scientific ideas. One student stated, “I expected there to be a clear-cut right or wrong experiment to do and the computer would say ‘this is impossible because in the world you can’t do this, you know.’” Some students struggled with these epistemological and pedagogical issues that emerged in several animated class discussions. For example, one student who reflected back to using the relation-based modeling tool (Model-it) stating she had been thinking “This isn’t any good because it is giving false information. I think that if children see it, they would believe it. I know when I saw something [an incorrect model] I believed it, even though it is on the computer and something that you created.”

Additional analysis supports this finding and indicates that students largely focused on the software as simulations rather than as models. “I like [Starry Night]... I feel like it gives you concrete information like scientific information and facts.” Data from the written pre/post test supports this finding, indicating that students thought computer models were predominantly useful for giving a visual representation, and that computer software in the classroom should
show something that can’t normally be observed, rather than thinking of modeling and simulation software as tools useful for helping students develop and refine their theories.

On a practical note, there were several aspects that impacted the implementation of the intervention that will be further discussed in the paper. As an example, our project found few strong modeling tools available for teaching K-8 science. Commercial sources present only a small number of valuable options (limited in modeling capability and learning goals) and some of the cognitively-strong educational software derived for research purposes is out-of-date or had some programming errors.

**Importance, Conclusions, and Future Work**

Overall, we believe that engaging pre-service teachers in learning about and using computer simulation models not only enables student teachers to address the technology standards that are becoming a key component of K-12 education, but can help them better understand the nature of science and perhaps even better teach science. Within this study, we found that such student teachers who learned about and used modeling tools significantly expanded their views about the available technology. We also found that such students were exposed to and challenged by a new epistemological and pedagogical perspective that many did not fully understand. We suspect that interventions such as this one would be more successful with longer-term and broader-based exposure such as use within science courses. Future work will entail finding additional tools that will better enable teachers to incorporate modeling into K-8 teaching, finding ways of matching student teachers’ goals for teaching and learning with the epistemological and pedagogical modeling perspectives, and working with more experienced teachers in the field to incorporate model-centered approaches in the classroom.

We look forward to having the opportunity to present this research in further detail at AERA 2004.

**References**


