Taking It to the Field: The Authentic Integration of Mathematics and Technology in Inquiry-Based Science Instruction

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Students' understandings of science are greatly enhanced by exposure to real-world phenomena in field-based settings. Field-based learning provides students with opportunities for using inquiry to formulate questions about the nature of what they observe. Inquiry into natural phenomena may well be expressed in mathematical terms. It can be aided by the use of technological tools for collecting and analyzing data, and reporting the results of research.
A project in which mathematics and technology are integrated into scientific inquiry in field-based settings is reported. Efforts to integrate mathematics, technology, and field-based learning into a preservice science methods course are described, as is the subsequent use of the resulting model during inservice workshops with teachers from three different elementary schools. Comments of participants in the course and the workshops are included.

Technology as a Tool in Scientific Inquiry

Throughout the country, there are many efforts to increase science learning opportunities for students through authentic and meaningful scientific inquiry. Such endeavors provide contexts for students to (a) think critically, explore phenomena, and solve relevant problems; (b) plan and conduct investigations in relevant settings; (c) gather and collect information to construct reasonable explanations and solutions; (d) engage in discourse about their ideas, explorations, and conclusions; and (e) use the tools of science, mathematics, and technology to aid in their investigation and communication efforts (International Society for Technology in Education, 2000; National Council of Teachers of Mathematics, 1989; National Research Council (NRC), 1996). To continue this reform movement, inservice teachers, and ultimately preservice teachers also need to be exposed to such contexts and also have the opportunity to learn science through inquiry. This project focused on the use of tools of science, mathematics, and technology by preservice and inservice teachers to engage in scientific inquiry through the investigation and communication of phenomena in field-based settings.

"Students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses" (National Science Board, 1991, p. 27). The desire and drive to answer questions and to solve problems are characteristic of those who engage in scientific work (American Association for the Advancement of Science, 1989, 1993; Duckworth, 1996; Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Nelle, Sachse, & Walton, 1990; NRC, 1996). Although science is a dynamic process, students are often not allowed to experience science in this way (Sprung, 1985; Weiss, 1994). As a result, the vast majority of students often view science as something that is static, a great wealth of facts known only by scientists that
students must learn in the context of classrooms (Songer & Linn, 1991; Mallow, 1985, 1986.) Learning opportunities that situate students in the field where authentic investigation and data collection can occur provide students with a more accurate view of the scientific process.)

Technology is a tool that supports authentic learning experiences in field-based settings as well as in the classroom. It allows students to collect and record information in the form of numerical data, written field notes, drawings, and digital images while in the field. Technology helps connect the field-based experiences to classroom learning by providing ways for students to easily and professionally display and analyze the data they collect in the field and communicate their findings so peers can share in their new-found understandings. As students work in relevant field-based settings, they use and develop skills necessary for scientific work such as formatting significant questions; developing methods of exploration; carrying out studies; and engaging in discussion with others about their discoveries. Technology supports the processes of wondering, exploring, and discovering, which are central to the scientific process. Through these authentic learning opportunities students construct their own understandings about the world around them. In this sense, science "is an active process....[It] is something students do" (NRC, 1996, p. 20).

Project Purpose

This project was a three-pronged effort to enhance preservice teacher education, provide inservice professional development, and to design a curriculum that authentically integrates science, mathematics, and technology in elementary science instruction. Working cooperatively, this project sought to construct "seed schools" that would provide models for how teachers might effectively and authentically integrate technology and mathematics into their inquiry-based science instruction. School administrators and classroom teachers, preservice teachers enrolled in methods classes and practicum field experiences in these schools, university faculty in science, mathematics, and technology education, and school district professional development staff comprised the critical supportive links to achieve the goals of this project.
Project Site

This project involved the collaboration of university faculty in science, mathematics, and technology education, preservice teachers enrolled in a science methods course, and the administration and faculty of three elementary schools. During the spring semester of 1998, preservice teachers were enrolled in elementary science methods at a large comprehensive, urban institution situated in a rapidly growing metropolitan area in the southwest. Of the 1300 students 64.8% were in elementary education. Students in education tend to be nontraditional, older than typical college students and live away from campus, yet within the metropolitan area. Students in the teacher education program are predominately female.

Traditionally, scientific inquiry is an underlying theme of the science methods course. This was evident in the choice of topics as well as the methods of instruction. For example, each semester, preservice teachers were engaged in a long-term study where they investigated factors important to plant growth. Teams of teachers decided on a question to explore regarding plant growth; designed an investigation to help them answer their question, collected and recorded data on spreadsheets and in journals; problem-solved and redesigned investigations as needed; and presented their results and findings to their peers using computer presentation software. As they engaged in their investigation as learners, they also explored the feasibility of using such approaches with their students (Davis, 1997). The purpose of this investigation, and other activities in the course was to facilitate preservice teachers' learning of science practices and effective pedagogy through their own meaningful scientific inquiry and use of technology, and to support them and their instruction in their school settings.

Preservice teachers completed their practicum field experiences in the partner elementary schools engaged in this project. Two of the schools had targeted math, science, and technology instruction as a priority for student learning. One was a mathematics, science, and technology magnet school. The faculty of the other school was involved in professional development in mathematics and science instruction through the school district. The third school was in the planning stages of becoming a professional development school to be housed on the university campus. Two of the three schools served at-risk populations of students.

Placing preservice teachers in these settings allowed for support from classroom teachers and principals for preservice teachers' work in schools with regard to inquiry-based science teaching and the integration of technology in classroom instruction. In addition, preservice teachers had the opportunity to see the relationship between theory and practice and to develop effective instructional practice.
Planning the Project

The purposes of this project were to emphasize the connections between science, mathematics, and technology in the teaching of science and to develop an appreciation of the importance of providing children opportunities to explore science in the field. One of the researchers teaches science education classes for pre and inservice elementary teachers. She was concerned about the first hand experiences preservice teachers were gaining through their practicums regarding teaching children science. Acknowledging that elementary teachers, the majority being female, have been marginalized and typically excluded from scientific experiences, it was her goal to provide them with authentic scientific experiences for preservice and inservice teachers. In so doing, she hoped to ground pre and inservice teachers' experiences in scientific inquiry, focusing on what it is like to formulate and investigate questions in appropriate settings and using authentic tools.

She approached university faculty in mathematics and technology education to further integrate the processes, skills, and tools from each of these areas into the pre and inservice teachers' experiences, in particular to integrate the use of technology in field-based scientific inquiry. The three faculty members collaborated for the purposes of revising the existing undergraduate elementary science methods course and strengthening its connection to the classrooms in which the preservice students would be placed. A cohort of preservice teachers in an elementary science methods course were placed as practicum students in two urban schools in a growing metropolitan area in the Southwest. The inservice teachers who would be working with these students would be participants in this project. This coordination of field-placements provided shared experiences for the preservice and inservice teachers and led to a collaborative project which authentically integrated science, mathematics, and technology in field-based settings.

Meetings were held among university researchers, school principals, school technology coordinators, and teacher leaders to determine and plan valuable experiences in science education for the inservice teachers in the project. The conversations centered on the need for authentic experiences in scientific inquiry and included discussions regarding appropriate choice and use of technological tools for scientific inquiry.

Thus, it was decided that both preservice and inservice teachers, working in collaborative teams, would engage in investigations that would focus on environmental issues relevant to the desert region. The environment was chosen as the overarching topic of study for teachers and students because of its relevance and importance to their everyday lives and that of the community in which they live and because this topic provided opportunities for
learners to acquire complex understanding inclusive of many disciplines addressed in local, state, and national science education standards. The project would:

- Address issues, events, problems, or topics significant in science and of interest to participants.
- Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings.
- Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge.
- Provide opportunities for teachers to connect and integrate all pertinent aspects of science and science education in appropriate contexts.
- Provide contexts for collaboration among teachers, teacher educators, and scientists (NRC, 1996, 59, 62, 70).

To link the tools with the investigation, we needed to provide technology training and then provide further experiences using the tools on site for scientific inquiry. The technology used for scientific inquiry were chosen for their size, weight, and ability to be used in field conditions. Portable computers were chosen that had the ability to connect to, and record data from, environmental probes. The probes, commonly available from scientific supply companies, can measure a variety of environmental conditions, although they were used here solely to measure air, soil, and water temperatures. In addition, digital cameras and disposable, film-based cameras were used to take photographs at the study site.

The Preservice Component

The preservice teachers were enrolled in an undergraduate elementary teacher education program at an urban university in the desert Southwest. Students at this university tend to be nontraditional, older than typical college students, and live off campus, yet within the metropolitan area. Students in this program are predominately female.

Each of the preservice teacher participants in this project were enrolled in the revised undergraduate elementary science methods course. Scientific inquiry became an underlying theme of most of the course. This was evident in choice of topics as well as methods of instruction. New aspects of this course included exposure to the Globe Project and its interactive World Wide Web site devoted to recording and reporting global climate change
using data provided by elementary and secondary schools throughout the world. This site was used to provide students with information about ways that schools were interacting with one another in collecting scientific data.

A major component of the revised course was a field trip to a National Recreation Area where preservice teachers used the methods they had learned throughout the semester as well as tools appropriate for scientific inquiry in the field. This field trip was facilitated by the university faculty in science, mathematics, and technology education and was designed to serve as a model for science teaching.

The theme of the field trip was using observational skills for scientific inquiry. Students were engaged in several activities to heighten awareness of their senses and how these senses can be used to collect information regarding their surroundings. As students moved through the park, they were periodically asked to use one or more of their senses to collect as much information as possible in different settings. For example, at one point they were all asked to find a place to sit alone and "be a rock"—to sit quietly and still use all of their senses to observe their surroundings. After a short period of time, students were asked to describe their observations. They noted such things as hearing birds that they could not see and the sound of the wind rustling through trees, shrubs, and mountain passes.

Members of the class hiked to a permanent natural water source in an otherwise desert environment. This site was chosen due to its permanent water source, the possibility of observing animals, and the abundance of vegetation which was more varied than elsewhere in the park. The water was teeming with organisms that could be sampled and measured. Upon reaching this destination, students were divided into three groups to carry out three different investigations. The topics of the investigations were: water, air, and soil temperatures, water organisms, and plant communities. Each group eventually performed each investigation.

To aid in their investigation, the students were given portable computers that could be used for word processing, drawing with pen technology, creating spreadsheets, and collecting data through the use of environmental probes. The students were also given digital cameras, data gathering tools such as tape measures, thermometers, electronic temperature probes, magnifying glasses, and rope.

The water, air, and soil temperature activity was designed to familiarize students with portable computers and temperature probes that have the capability of collecting, displaying, and storing temperature data. Given these tools, the students were to formulate investigative questions and determine how to answer these questions. Some of the student-generated investigations were designed to determine "if soil was colder than water," "whether
ambient air differed in shady or sunny areas,” and “if sunlight reflected from clothing was warmer than sunlight reflected from hair.” These investigations provided a purpose for students to learn how to use portable computers and probes to collect and record temperature data.

The water organism activity was designed to expose students to sampling techniques and the use of the drawing capabilities of the computers. Questions were asked of the participants about whether different organisms might exist in the pond compared to the stream and if depth and temperature impacted the results. Samples of water organisms were collected by seining the pond and the stream. Temperature was taken using computers with temperature probes. The students categorized the organisms by looking for commonalities through magnifying lenses and recording the locations of where the organisms were gathered. The numbers of organisms in each category were recorded using the spreadsheet application of the computer. Drawings of the different organisms were made using the pen technology available with the computers. These files were saved for future use in multimedia presentations.

The plant communities activity was designed to acquaint students with measurement and observational techniques. Students designated communities by “capturing” all of the plants that could be contained in a loop made out of a 10 meter length of rope. The students first catalogued the plants, conducting a census of the population contained within the loop of rope. Students then categorized the plants by type, height, breadth, leaf type, smell, whether or not they had bark, and so forth. These data were recorded with the spreadsheet and drawing applications of the computers as well as by taking pictures of the communities and individual plants using digital cameras.

Accommodations were made for physically handicapped participants as well as participants who chose not to hike so that they were able to conduct similar investigations. A wheelchair accessible area of the park was used to conduct the temperature differences and plant communities activities. The students who did not hike used the computers more extensively than those who used their time to hike to the water source. These students participated in an alternative activity which involved describing their surroundings using the word processing and drawing capabilities of the computer. They “beamed” their files to each other and tried to identify the specific topics of observation based on what was contained in the files. “Beaming” is a function that allows for a wireless transmission of data between machines.

At the end of the day, the entire group gathered to talk about their experiences and how they broadened the students’ definitions of science. The students reflected upon how this capstone experience combined with the activities in their science methods course might relate to future
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activities with their prospective elementary students. Due to time constraints, the university faculty used the field trip data to make multimedia presentations as a demonstration of what could follow such a field trip.

The Inservice Component

The inservice teacher participants worked at three elementary schools in a rapidly growing, urban school district. A key to the success of this project was the early collaboration between university faculty in science, technology, and mathematics education and the principals and technology coordinators of the three participating elementary schools. A relationship existed between the university faculty and school personnel based on early field placements of preservice teachers. Discussions centered on the idea of making science and mathematics instruction more meaningful to elementary students. Teachers at these schools were using several environmental curricula package but some were lacking confidence and expertise in methods of teaching with these materials. It was hoped that this collaboration would help to facilitate professional growth around scientific inquiry in the field-based settings using the various curricula and technology. This was something that the elementary school teachers wanted and were in need of, and that the faculty involved in this project were capable of providing.

A plan for professional development resulted from this collaborative effort between school personnel and university faculty. The professional development was designed as a one and one-half day workshop consisting of an introductory session, a field-based experience, and computer laboratory time. During the introductory session, participants reflected upon their experiences as learners and teachers with scientific inquiry, highlighting the investigations in which they and their students had engaged. Some teachers and their students had already made valuable links to field study and the use of technology. The value of technological tools in field-based inquiry was discussed and examples were provided using the multimedia presentations the university faculty had created representing the preservice teachers experiences.

Technology-based tools for field-based, scientific inquiry were introduced next. Specifically, participants were taught how to use portable computers, temperature probes, and digital cameras. Participants were divided into small groups; each group was assigned a computer. The word processing, drawing, and spreadsheet functions of the operating system used by the computer were similar to a software application with which the teachers were familiar. Once the teachers had explored the main difference, the use
of the stylus (or pen technology), the teachers were taught to “beam” their finished works to other groups. The temperature probe and probe software were introduced next. Cups filled with ice, soil, and warm and cold water were distributed. With guidance, the teachers recorded data collected with the probes from the various containers and compared temperature differences between mediums.

The field-based component consisted of a group trip to an outdoor site that exhibited environmental diversity. One field trip was to a local water treatment facility, that, interestingly enough, doubled as the site of a regional bird sanctuary. Another field site was located on the university campus as an example of a place students of the planned professional development school could visit. This site is a desert demonstration garden of approximately two acres containing a wide variety of arid plants with paths winding throughout and a fishpond at its edge. While on site, participants engaged in the same activities as those used by the preservice teachers described above. University faculty facilitated this process by posing questions of participants related to their environment.

When the teachers returned from the field trip, they were given the task to create a multimedia presentation to demonstrate what they had learned in the field. Data from the computers and the digital cameras were uploaded into each group’s desktop computer. Participants then organized their multimedia presentations using storyboards. With storyboards, boxes are drawn to represent slides, and the topic for each slide is written in the boxes. The storyboard is then used as a key for converting content to a multimedia format. Slideshows were created using multimedia software. The groups chose their own styles for sharing what they had discovered and how they had grown from their experiences. Some of the groups concentrated on one of the activities while others made presentations on all three. The workshop concluded with the participants presenting their projects and reflecting on their experience. Teachers at one elementary school even delivered a multimedia presentation of their experiences gained from the workshop to their entire school faculty at a later date.

Evaluation

At the beginning of the project, preservice teachers were asked a series of questions regarding their experiences with, and feelings about, the teaching and learning of science and mathematics. In addition, they were asked to share their own experiences with respect to learning about science and mathematics in outdoor settings. Similar questions were asked of the inservice teacher participants prior to their workshops.
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Given their own experiences as students, both preservice and inservice teacher participants expressed negative feelings regarding past science learning. This was expected based on findings that suggest that the "school" science to which the preservice and inservice teachers were likely exposed was not related to their lives (Sprung, 1985; Weiss, 1994). They were taught a set of facts to be memorized. They followed the example of teachers working in labs rather than engaging in authentic investigation.

I can only remember a couple of times science was held outside. Most of my science classes were either lectures or labs that involved instruction. However, I do think that teaching science outside once in awhile is good. It breaks the monotony of classroom lectures. [Preservice teacher]

I really don't understand what science is all about... The only class I enjoyed was geology. We actually went to a wash to explore what was out there. [Preservice teacher]

As a student, my experiences were very traditional in math and science. I did have the opportunity to do some experimentation and lab work, but none of these were student-generated ideas. [Inservice teacher]

While preservice and inservice teachers recognized the importance of hands-on experiences in the learning of science, they were not able to base this perception on their personal experiences as science learners in school settings.

I have not had a lot of hands-on experience with science at school. I remember taking a few field trips in school; it wasn't usually something we brought back to the classroom. [Preservice teacher]

I never collected data outdoors and feel like I missed out. I would love to do that with my students if I knew how. Much more learning goes on when students have hands-on activities and have to think, rather than a boring book they don't relate to. [Preservice teacher]

Field trip learning is something I've done lots of as a parent. From what I've seen at school, our students need more of it because their science and math learning experience base is minimal. [Inservice teacher]
Following the preservice science methods course and inservice professional development, participants were asked what they had learned and how this would impact their teaching practices. Preservice teachers felt there was a change in their perceptions of how science should be taught. They seemed to come to the realization that science is something you do with children. This belief was reinforced for the inservice teachers who already had experience using hands-on activities with their students but needed guidance in making these experiences relevant to the students and the curriculum.

I’ve changed my thoughts on science—it can work into the curriculum and be hands-on for my students—I’ve enjoyed learning and observing new things this semester and will use many of these ideas in my classroom. [Preservice teacher]

It was wonderful to have 1 1/2 days to really do what we were learning! [Inservice teacher]

It’s so much more beneficial to actually have that hands-on experience! It’s not just for kids anymore! [Inservice teacher]

It appeared that the preservice teachers made the transition from seeing their goal as learning how to use the computer to understanding that the goal was to use the computer as a tool in authentic scientific inquiry. The inservice teachers, who were more connected with the everyday needs of classroom instruction, immediately began to plan the ways in which they would use technology for field-based inquiry with their students.

Computers have to be used in the same way experts use them to bring about the full experience of science and how scientists work. [Preservice teacher]

At the first grade level—I’ll use more of the digital camera and multimedia applications. I may be able to use portable computers out in the field, but that would be more technical and I’d have to have an adult to help students use the computers. [Inservice teacher]
CONCLUSION

The revised science methods course and the inservice teacher workshops were successful in emphasizing the connections between science, mathematics, and technology in the teaching of science. Preservice and inservice teachers also indicated an appreciation of the importance of providing children opportunities to explore science in the field. Science is something that children understand best if they have the opportunity to explore it in authentic environments (Brown, Collins, & Duguid, 1989). The participants in this project gained specific examples of places to go with students, types of activities to provide them, technological tools to be used to collect and analyze data, communicate results, and ways in which mathematics can be used to describe the science students explore.

References


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1. Field is defined here as any context in which there is opportunity for authentic investigation and data collection.
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