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ABSTRACT

Teachers' subject matter knowledge is a particularly important issue in science education in that it influences instructional practices across subject areas and at different grade levels. This paper provides an overview of efforts to develop a unique elementary science methods course and related field experience through a partnership between Science Education and the Department of Entomology at the Pennsylvania State University. The partnership was aimed at providing prospective elementary teachers with meaningful opportunities to learn life science concepts using insects as models, engage in scientific investigations under the guidance of entomology faculty and graduate students, explore children's ideas about science, and consider implications for teaching and learning science for understanding. The program collaboration and related course experiences are described. (Contains 27 references.) (WRM)

ENHANCING THE *SCIENCE* IN ELEMENTARY SCIENCE METHODS: A COLLABORATIVE EFFORT BETWEEN SCIENCE EDUCATION AND ENTOMOLOGY

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Background & Purpose

It has been suggested that children's attitudes and interests in science are greatly influenced by their experiences with science in the elementary school. Children begin school with a natural curiosity about the world in which they live; however, by the time they complete the elementary grades many of them have developed a dislike for science (Beiswenger, Stepans & McClurg, 1998; Hall, 1992). Sadly, science teaching and learning is an all-too-often neglected aspect of the elementary curriculum.

Because they tend to have a limited background in science, elementary teachers often lack confidence in their own ability to understand and teach science successfully. These negative attitudes can greatly influence their effectiveness as teachers of science (Kramer, 1988). For example, science is typically taught at the end of the school day (if at all), and activities are usually textbook-based. Rarely are there opportunities for meaningful inquiry (Beiswenger, Stepans & McClurg, 1998), exploration, and question-driven investigations. In addition, it is not uncommon for teachers to actually transmit a dislike of science to students (McDermott, 1990).

Teachers' subject matter knowledge is a particularly important issue in science education in that it influences instructional practices across subject areas and at different grade levels (Brophy, 1991). Recent studies have reported that many prospective teachers do not have even the most basic understanding of their disciplines as they begin their teacher preparation programs (Ball 1990; Ball & McDiarmid, 1990; Cochran & Jones 1998). In general, the subject matter

knowledge of prospective teachers has been characterized as unorganized, superficial, and inaccurate (Guess-Newsome & Lederman, 1993; Lederman & Latz, 1993). When it comes to science, prospective elementary teachers' knowledge has been described as limited, narrow in perspective, and characterized by a lack of understanding of the nature of science (Anderson & Mitchener, 1994; Scharmann, 1988; Wenner, 1993). In addition to their limited science subject matter knowledge, elementary teachers often hold the same misconceptions and alternative frameworks about science as their students (Hashweh, 1987; Hollon, Anderson & Roth, 1991; Smith & Neale, 1989).

College and university science programs have remained essentially unchanged for decades (Yager & Penick, 1990), as have the science content requirements of teacher preparation programs (Zeitler, 1984). The typical science credit requirement for prospective elementary teachers consists of two to three courses across the biological, physical, and earth sciences. In truth, we know very little about how these courses prepare students for careers in the sciences, let alone science teaching (Yager & Penick, 1990).

Most subject matter courses for teaching science are offered within academic departments where prospective science teachers generally take standard departmental courses. Many science faculty seem to believe that the effectiveness of a prospective teacher will be determined by the number and rigor of courses taken in the discipline (McDermott, 1990). Aside from teaching these courses, faculty in the sciences typically have no involvement in teacher preparation programs. This is not surprising given that the education of prospective teachers is considered peripheral to the mission of science departments.

What is apparent and of concern is that the ways in which science is portrayed in undergraduate courses do not accurately represent authentic science (Anderson & Mitchener, 1994), especially regarding the nature of science. Traditional science content courses are typically taught in a large, lecture-style setting with a separate, verification-format laboratory. Rarely do these courses provide prospective teachers with opportunities to design and engage in inquiry-oriented, scientific investigations. To make matters worse, the scientific concepts and

relationships that prospective elementary teachers are usually exposed to are not representative of or connected to those that they will likely be expected to teach (Cochran & Jones, 1998).

Elementary science teaching has been characterized by a heavy science process component (Zeitler, 1984) that incorporates observing, classifying, hypothesizing, and making inferences. In light of recent reform efforts in science education, there is an increased emphasis on engaging children in doing scientific investigations -- asking scientific questions, investigating aspects of the world around them, and using observations to construct reasonable explanations for the questions posed (NRC, 1996). Unfortunately, elementary teachers themselves lack these types of inquiry-based experiences as learners of science. The lecture-based content courses that prospective elementary teachers take generally encourage passive learning and focus on the recall of scientific information. Moreover, the breadth of topics covered in the typical college course allows little time for acquiring a sound grasp of the underlying concepts. Undergraduates become accustomed to receiving knowledge, rather than helping to generate it (McDermott, 1990) and rarely have opportunities to engage in meaningful activities that incorporate science content and inquiry skills.

Similarly, laboratory experiences, when required, do not address the needs of prospective elementary teachers either. The format is usually based on the verification of known principles. Students have little opportunity to make observations and perform the reasoning involved in formulating these principles (McDermott, 1990). In addition, the laboratory equipment used at universities is often not available in school districts. No attempt is made to help prospective teachers plan laboratory experiences that utilize simple materials and apparatus.

Another potential drawback of science content courses is that instructors, often scientists, rarely model pedagogical approaches that emphasize teaching science for understanding, which is currently at the forefront of science education reform (NRC, 1996). Teachers are expected to identify their students' prior knowledge and skills; use appropriate strategies to enable the children to confront their prior knowledge and develop process skills; and engage students in assessing what they have learned (Harlen, 1998). This form of teaching utilizes multiple

instructional strategies such as cooperative group work, opportunities to discuss and debate ideas, and classroom activities that focus and support student inquiry. Rarely are these strategies part of large lecture science classes that serve as examples of pedagogy whether intended or not. It is widely accepted that prospective teachers learn more than just content from content courses (Cochran & Jones, 1998; Hauslein et al., 1992; NRC, 1996). Learning to teach is a complex process that is influenced by the experiences that teachers themselves have as learners (Britzman, 1986; Holt-Reynolds, 1992). As a result, within the context of reform, teachers are once again being asked to teach in ways that are inconsistent with their prior science learning and instructional models.

In response to these issues, educators have recommended that teacher preparation programs be designed specifically to assist preservice teachers in constructing robust subject matter knowledge, as well as preparing them to teach that subject matter for understanding (Borko & Putnam, 1994; Cochran & Jones, 1998; Tobin, Kahle, & Fraser, 1990; Zembal, 1996; Zembal-Saul, Starr & Krajcik, in press). The purpose of this contributed paper is to provide an overview of one such effort – a unique elementary science methods course and related field experience that developed out of an ongoing collaboration between Science Education and the Department of Entomology at The Pennsylvania State University. This partnership was aimed at providing prospective elementary teachers with meaningful opportunities to learn life science concepts using insects as models, engage in scientific investigations under the guidance of entomology faculty and graduate students, explore children's ideas about science, and consider implications for teaching and learning science for understanding. What follows is a description of the collaboration and related course experiences.

Elementary Science Teaching & Learning Course

At The Pennsylvania State University, elementary education majors are required to take three science content courses -- one each in the life, physical and earth sciences -- prior to enrolling in the elementary science teaching and learning course (methods), which is typically taken during the last semester prior to student teaching. Most of these courses are offered within

the College of Science and are characterized by many of the same limitations described previously.

In light of what is known about the science subject matter preparation of preservice teachers, the elementary science teaching and learning course has been designed around several central areas of emphasis. First, prospective teachers are actively engaged in learning science throughout the course. A conceptual change orientation drives instruction; concepts are selected based on the *National Science Education Standards* (NRC, 1996) K-4/6-8 content guidelines; and inexpensive materials that are available at Wal-Mart or the local grocery store are used. The purpose of this strategy is for preservice teachers to experience, as learners, a more conceptual approach to science teaching and learning -- one that is consistent with contemporary reform efforts in science education. At the end of each semester, many education students report that this course was their first experience learning science in this way.

Reflection is another critical aspect of the course. Preservice teachers are supported in their attempts to engage in critical reflection in a number of areas, including their past and present experiences as science learners, their beliefs about the nature of science and scientific inquiry, their emerging *theories* regarding teaching science for understanding and the role of children's ideas/thinking, and their experiences *testing-out* these theories with elementary children in school settings.

The science teaching and learning course is one of three subject-specific methods courses and complementary field experience taken during what is known as the Discipline Inquiry (DI) Block. As mentioned previously, this block is typically taken during the last semester prior to student teaching. Beginning in the fourth or fifth week of the semester, education students are in schools approximately two days every week.

For several years the DI Block had been offered during the summer, presenting the challenges associated with providing a quality program in the context of a condensed meeting schedule and field placement restrictions. Interestingly, it was this challenge during the summer

of 1998 that resulted in the creative and fruitful collaboration with the Department of Entomology described here.

The Science Education – Entomology Connection

The faculty of the College of Agricultural Sciences were natural collaborators in education due in part to their shared mission of outreach and public education. The Department of Entomology, in particular, has been actively engaged in sponsoring educational programs, such as The Great Insect Fair (annual community-based outreach and education event), Bug Camp for Teachers (summer course for practicing teachers), and Bug Camp for Kids (summer program for elementary children) for a number of years. When the challenge of providing a summer version of the elementary science teaching and learning course arose, science education and entomology faculty were already working together to develop an applied life science course for prospective elementary teachers using insects as models. The entomology faculty were eager to provide assistance, viewing it as an opportunity to learn more about the education majors for which the applied life science course was being developed. As a result, two week-long summer education programs for elementary children, Bug Camp for Kids and Advanced Bug Camp, were integrated into the summer version of the DI Block, making possible interactions among prospective elementary teachers and children around science content. These experiences were complemented by a school-based summer enrichment program in a local school district.

Bug Camp for Kids

Bug Camp for Kids, which was in its fourth year of implementation, was a week-long day camp attended by approximately forty-five children, ranging in age from eight to twelve. Campers participated in daily field studies to observe and collect insects. In addition, they participated in a variety of engaging laboratory investigations that used insects as models to learn a broad range of biological, ecological, and environmental concepts. Instructors placed a heavy emphasis on using observations of insects to generate questions. In addition, the findings of field studies and investigations were reinforced through simulations, role playing, insect *games* and songs. The roles of the preservice teachers included conducting pre/post content interviews with

children based on the program outcomes developed by Bug Camp coordinators; *adopting* groups of students and facilitating their learning activities; and creating a multimedia artifact (electronic slide show) that chronicled the children's experiences throughout the week. During their involvement in the camp, prospective teachers kept a semi-structured journal that challenged them to consider children's learning, as well as their own subject matter learning, and to reflect on implications for teaching science in the context of elementary schools.

Advanced Bug Camp

The Bug Camp experience was immediately followed by another week-long entomology program for children, Advanced Bug Camp (ABC). Unlike Bug Camp for Kids, which was an established program, ABC was offered for the first time in the summer of 1998. It was developed as a result of the success of Bug Camp. That is, there was a perceived need to offer new and more challenging science learning experiences for veteran Bug Campers, some of whom had attended Bug Camp for two and three consecutive summers. Therefore, ABC was designed to engage young insect lovers (ages 10-12) in scientific inquiry projects using insects. Campers began the week by visiting a number of laboratories where research on insects was being conducted. Then, with the assistance of entomology and education mentors, children worked in pairs to design and conduct investigations related to questions they developed about insect physiology, behavior, etc.

Instructors emphasized the role of observation and questioning in science, experimental design considerations (e.g., variables, repeatability, data collection, etc.), the role of evidence in developing explanations, and interactions within a scientific community. Great efforts were taken to create a community of young scientists. For example, each day ended with a round table discussion in which groups shared their progress, defended their findings with evidence, and generated questions for further exploration. The week culminated with a research conference in which children presented their projects to the group in a more formal setting. Again, children were encouraged to end their presentations with questions for future research.

Education students took on a much more central and active role in the Advanced Bug Camp experience. They participated as active members of a research team. These teams consisted of a pair of children, a pair of education students, and an entomologist. The preservice teachers were responsible for conducting pre/post interviews with children that focused on the nature of science and scientific inquiry, facilitating and participating in the inquiry-based investigations, and providing leadership with technology (e.g., multimedia research presentations). Throughout the week, the prospective teachers documented the investigation in which they participated, analyzed children's ideas about the nature of science, and considered implications for teaching science in the context of elementary schools, which included making connections to the National Science Education Standards (K-4 and 6-8 Inquiry and Life Science content standards).

As might be expected, a great deal of preparation was necessary to support the implementation of such an ambitious project. Of these preparations, an orientation session for mentors turned out to be critical to the success of Advanced Bug Camp. During this session, entomology mentors (faculty and graduate students) were introduced to education mentors (elementary education students). These introductions included an opportunity to share concerns about the upcoming program. Without exception, entomology mentors expressed their worries about working with children and education mentors shared their uneasiness with science content related to insects. One prospective elementary teacher eased some of the tension by coining the summer catch-phrase, "We won't squash the bugs if you don't squash the kids!"

The orientation session also engaged mentors in an activity designed to raise considerations associated with assisting children in designing scientific investigations. These interactions among mentors were crucial in establishing the potential contributions that each individual would make to their research team.

School-Based Enrichment Program

Immediately following the bug camp experiences, preservice teachers spent four weeks in a school-based summer enrichment program for children in first through fifth grades, the

emphasis of which was reading and mathematics. Whereas the science teaching and learning course was heavily integrated with the bug camps and conducted on-site in the Department of Entomology, education students attended the school-based enrichment program each morning and returned to the university in the afternoons to attend their methods courses.

Although science was not central to the summer enrichment program, the preservice elementary teachers were responsible for planning and implementing a two-day culminating event that involved teaching with insects. Preparing for this event provided a context for experiences within the science teaching and learning course. For example, prior to planning instruction, education students investigated children's ideas/thinking about science content related to insects. Similarly, attempts to enact their instructional plans provided the basis for critical reflection on practice.

Analysis of preservice teachers' instruction revealed several patterns. In general, the activities they prepared were student-centered and engaging -- children were active participants in the learning process. Instruction was developmentally appropriate, and a number of attempts were made to integrate children's literature, music and art in meaningful ways. Not surprisingly, many Bug Camp activities were modified and used in some way, and having children generate questions from their observations of insects was common. Unfortunately, issues with preservice teachers' science subject matter knowledge were evident, and attempts to engage children in inquiry fell short of resembling Advanced Bug Camp.

Lessons Learned

As would be expected, limited experience engaging in scientific inquiry during Advanced Bug Camp was not sufficient to alter preservice teachers' beliefs or influence their thinking about designing science instruction. However, evidence from artifacts collected in the science teaching and learning course suggests that participation in the scientific inquiry project was valuable in other ways (see Zembal-Saul, Boardman, Severs & Dana, 1999). First, engaging in scientific inquiry provided an opportunity for prospective teachers to learn science in a way that they had never experienced previously -- a way that represented the authentic nature of science.

When asked to reflect on that experience by considering connections to the National Science Education Standards (NSES) (NRC, 1996), several students commented that the entomology faculty had done an effective job of incorporating the inquiry standards into their program. They were surprised to learn that the entomologists actually knew very little about the NSES document. This fueled discussion regarding the nature of science and scientific inquiry and its role in school science, which provided a context for education students to reconsider the goals of contemporary reform efforts in science education.

Another important aspect of engaging preservice elementary teachers in scientific inquiry stems from the model of implementation used in Advanced Bug Camp. By working as a member of the research team, the education students were essentially *lab partners* with children. This gave them an opportunity to explore children's ideas about science content and the nature of science, and to monitor children's thinking as they engaged in learning science via inquiry. Because an entomologist was available to aid with content and experimental design issues, the prospective teachers were able to focus on issues of learning -- both their own and that of children. As they reflected, many of the education students acknowledged that the ABC experience changed their views about what elementary children are capable of accomplishing when provided with appropriate support and guidance.

Finally, the collaboration between entomology and education was successful for two reasons. First, the strong emphasis on education embedded within the mission of the college in which the Department of Entomology resides allowed the collaboration to progress with institutional support for the faculty and graduate students involved. It is the experience of the authors that this is rarely the case when dealing with colleges of science. Second, the collaboration was an equitable one. Everyone involved had something to contribute that was vital to the success of the summer programs for children. Likewise, everyone was involved in learning something valuable which contributed to their own development as a result of their involvement. An added benefit was that the balance in roles emerged naturally from the design of the program.

In conclusion, much work remains to be done in order to minimize the gap between the vision of reform and the reality of classrooms. While elementary science methods courses attempt to assist preservice teachers in learning to teach science for understanding, it comes as too little too late. Education students need multiple opportunities to experience learning science in more conceptual ways that better represent the authentic nature of science prior to their advanced coursework in teacher education programs. The professional development of practicing teachers needs to be considered concurrently if there is to be any hope of providing preservice teachers with opportunities to translate their emerging ideas about teaching and learning into practice. Although the challenge is daunting, it is our contention that collaborative efforts, such as the one described here, will play a pivotal role in improving the situation and demonstrating that teacher preparation and development is the responsibility of the university community, not merely that of colleges of education.

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