

LEARNING ABOUT SCIENCE INQUIRY AND SCIENCE TEACHING AND LEARNING: A TECHNOLOGY-ENHANCED APPLIED LIFE SCIENCE COURSE FOR PROSPECTIVE ELEMENTARY TEACHERS

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Abstract:

Recent trends in science education call for greater emphasis on the role of inquiry in science teaching and learning (AAAS, 1992; NRC, 1996, 2000), which includes designing and conducting experiments, collecting and interpreting data, giving priority to evidence and developing scientific explanations. Unfortunately, this approach to science learning and teaching presents new challenges prospective teachers as many have never experienced learning science in this way. This paper will describe an innovative applied life science course developed specifically for prospective elementary teachers by a team of faculty and graduate students in entomology and science education. As part of their experiences in the course, *Teaching with Insects*, prospective teachers engaged in an original science investigation using insects familiar to elementary classrooms. In addition, they had opportunities to interact with and teach children in a carefully guided environment. Research on the experiences associated with this course (Haefner, 2001; Haefner & Zemba-Saul, 2001, 2002) suggests carefully crafted experiences engaging prospective teachers in science inquiry can support the development of more appropriate understandings of science and school science. However, findings also revealed that prospective teachers were likely to experience difficulties with various aspects of the experimental design, as well as the explanation building process (Haefner, 2001; Haefner & Zemba-Saul, 2001, 2002). In response, an intervention was developed using *Progress Portfolio*, a tool designed to promote reflective inquiry during learning in resource/data-rich environments (Loh et al., 1998). Continued research on this course (Avraamidou, Haefner, & Zemba-Saul, 2002; Haefner, Avraamidou, & Zemba-Saul, 2002) has indicated that technology scaffolds such as those provided by *Progress Portfolio* assisted prospective elementary teachers in developing evidence-based explanations.

Introduction

Recent trends in science education call for greater emphasis on the role of inquiry in science teaching and learning (AAAS, 1992; NRC, 1996, 2000). While inquiry in science learning is not a new idea (Bybee, 2000; Deboer, 1991; Trowbridge & Bybee, 1990), the renewed emphasis reflects a distinct shift away from *science as a process* and asks that students be engaged with scientific questions where they collect and interpret data, give priority to evidence to construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others (NRC, 1996, 2000). By engaging in science inquiry, learners identify their assumptions, use critical and logical thinking, and consider alternative explanations (NRC, 1996).

Unfortunately, this approach to science learning presents new challenges for students and teachers and the question becomes one of how to support learners as they participate in complex, data-rich investigations of scientific phenomena that require giving priority to evidence and constructing and evaluating scientific explanations? Loh and colleagues (1997) explain, “The complexity of open-ended investigations poses difficulties for groups of students who must continually negotiate plans and share understandings throughout an investigation” (p. 1). Not only do students struggle with organizing evidence and interpreting results, they often leave important questions unanswered when they are unable to make critical connections across various aspects of their investigations. Furthermore, how do we support prospective and practicing teachers in orchestrating these types of learning opportunities for their students when most have not experienced learning science in this way themselves? Inquiry has not been a prominent feature in science classrooms (NRC, 1996; Tamir, 1983) or in science teacher preparation (Zemba-Saul, Blumenfeld, & Krajcik, 2000). As a result, many prospective teachers lack both experience with and knowledge of how to teach science as inquiry. Therefore, the renewed emphasis on inquiry has exposed a serious gap in prospective teachers’ preparation to support children’s learning science as inquiry.

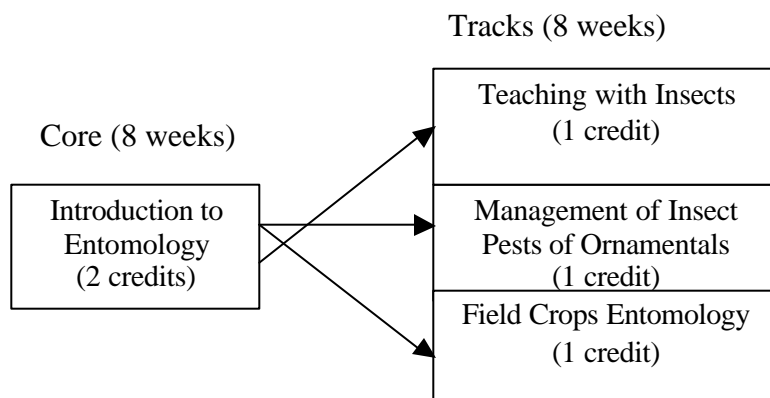
The literature suggests that to develop robust understandings of science and science teaching and learning, prospective teachers need a series of diversified experiences. Some of these experiences should be part of learning science and others part of learning to teach science (Boardman, Zemba-Saul, Frazier, Appel, & Weiss, 1999; Cochran & Jones, 1998; Even, 1993;

Hauslein, Good, & Cummins, 1992; Mellado, 1998; Stoddart, Connell, Stofflet, & Peck, 1993; Tamir, 1983). For example, researchers recommend powerful content-specific preparation in ways that are consistent with how prospective teachers will be expected to teach (Borko & Putnam, 1996; Hashweh, 1987; Hauslein et al., 1992; Putnam & Borko, 2000). Similarly, others recommend earlier and more frequent experiences teaching children (Borko & Livingston, 1989; Cochran & Jones, 1998; Gustafson & Rowell, 1995; Hollingsworth, 1989; Lederman & Guess-Newsome, 1991). Some of the more successful approaches that reflect these suggestions include alternative experiences in teaching and learning courses, as well as content courses developed specifically for prospective teachers. To support learning to teach in inquiry-oriented ways, we developed a subject matter course that engaged prospective teachers as learners in scientific inquiry appropriate for classrooms. In addition, while learning about scientific inquiry for the classroom, prospective teachers also had opportunities to interact with and teach elementary children.

Subject Matter Course for Prospective Elementary Teachers

Teaching with Insects is an applied life science course designed especially for prospective elementary teachers by a team of faculty and graduate students from Entomology and Science Education. The course was a continuation of a prior collaboration (Boardman et al., 1999) and intended to provide opportunities to learn about science inquiry (NRC, 1996, 2000) by engaging prospective teachers in an original science investigation. Teaching with Insects was designed to accompany a service course, Introduction to Entomology, offered by the Entomology Department. Together the two courses were offered as a 2/1 - credit package, and followed a core/track sequence. Introduction to Entomology (core) was taken first during the first 8-weeks of the semester. Upon successful completion of the core course, students entered a specialty course called a track for the remaining 8-weeks of the semester. Each track was designed to focus on entomology concepts relevant to a specific major (Figure 1). For example, Teaching with Insects was a track developed for elementary education majors. Other tracks included management of insect pests of ornamentals, field crops entomology and apiculture.

Figure 1. Illustration of the core/track, 3-credit package offered by the Entomology Department.



Introduction to Entomology

Introduction to Entomology introduced basic entomology concepts such as internal and external anatomy, structural diversity, behavior, natural history, and integrated pest management. Students met twice a week for lecture and once a week for a laboratory session. Although the lecture followed a typical large lecture format, it was co-taught by professors who were dynamic and interactive. They presented topics and concepts in the context of personal experiences and real-life examples and had a genuine interest in their students. Even in lecture, they interacted with everyone and learned nearly all 100 students by name.

The professors of Introduction to Entomology were interested in student learning and structured assignments in order to push students beyond basic memorization of the material. To encourage students think differently about particular concepts, they developed assignments that required students to approach problems from different perspectives. For example, rather than write a standard essay on a pesticide, students constructed an obituary for DDT. This task encouraged students to look beyond what they already knew about DDT and the negative impacts the pesticide had on the environment. In completing this assignment, students considered the social and political conditions under which DDT was developed and recognized how many human lives it saved. The DDT assignment was a precursor to an Integrated Pest Management (IPM) unit that explored alternatives to the chemical treatment of pests. In another

assignment, students documented travel between two locations on campus using the navigational taxes of insects. This assignment followed a lecture on how insects navigate from place to place and required students to apply this information to their own experience traveling across campus. Another feature of the lecture presentations was the extensive use of multimedia and handout materials. Lectures were given using PowerPoint™ presentations that included hotlinks to sites on the WWW. Lectures usually included an organizational outline or printed notes distributed at the beginning of class, as well as occasional demonstrations to clarify a concept. After each class, the PowerPoint™ slides and all supplemental information were available on the course website.

Weekly laboratory sessions reinforced concepts presented in the lecture and included topics such as internal and external anatomy, taxonomy and classification, and population sampling. The labs were taught by entomology teaching assistants, but overseen by the professors in charge. Because of the small number of students in each section, it was during the laboratory sessions that prospective teachers interacted with each other on a more personal level and got to know one another.

In addition to essays and homework assignments, the major assessment components were lecture and laboratory exams and an Integrated Pest Management (IPM) Project. All students, regardless of the track they entered, completed the same assignments with the exception of an IPM Project. Most students identified a plant and an associated pest and developed an integrated pest management plan. The project for the education students was tailored to meet their needs as prospective teachers. Rather than focusing on a particular pest, the prospective teacher's project centered on learning about insects common to elementary classrooms. Specific insects and Arthropods were purposefully pre-selected by the instructors of the Teaching with Insects track and assigned to prospective teachers as project topics. The insects were selected based upon basic characteristics and abilities to demonstrate science concepts appropriate for an elementary classroom.

The project had multiple components and to complete it, the prospective teachers worked in small groups. Overall, the goal of the project was that prospective teachers would become experts on their insects. This included not only the general biology, but also knowledge of current research associated with the insect, as well as potential educational applications of the

information for elementary classrooms. To understand more about the biology, the prospective teachers researched the insect's natural history and developed guidelines for maintaining a culture in captivity. The purpose of the task was for prospective teachers to become knowledgeable about their insects and comfortable regarding care and maintenance of a culture. Moreover, through these activities the prospective teachers became familiar with the insect's general characteristics and unique behaviors and adaptations. To learn about scientific research, the prospective teachers interviewed a research entomologist. In the discussions with the scientists, they explored the types of questions asked and the methodologies employed to answer those questions. Through their interaction with research scientists, prospective teachers were introduced to various purposes and methods of research. It was hoped that through these conversations they would gain insight into how scientific knowledge is generated and tested. Finally, to make the connection with elementary classrooms, prospective teachers identified ways in which their insects could be used to illustrate life science concepts appropriate for young children. They developed classroom activities and lesson plans that were consistent with the *National Science Education Standards* (NRC, 1996) and compiled an annotated bibliography of useful resources for using insects in the classroom. In doing so, the prospective teachers were introduced to current reform initiative in science education. All of this information was compiled into a report and presented at the end of Introduction to Entomology.

Teaching With Insects

Teaching with Insects was designed to apply concepts introduced in Introduction to Entomology. The primary purpose of the course was to engage prospective teachers in an original science investigation. However, the course also provided opportunities to consider children's science learning. For many, this was a new and more conceptual approach to science learning not previously experienced as learners. Many prospective elementary teachers enter teacher education programs with the belief that science learning should be hands-on and fun (Gustafson & Rowell, 1995; Nickles & Walter, 1998). The experience in Teaching with Insects was designed to counter this notion with a more substantive approach grounded in the prospective teachers personal learning experiences.

The Teaching with Insects track was developed from a social constructivist and conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) framework. The constructivist approach to learning is a leading theoretical position in education (Treagust, Duit, & Fraser, 1996) and emphasizes the manner in which learners construct knowledge. From a constructivist perspective, knowledge is not passively received but is built upon by the learner in a socially mediated context (Prawat, 1993). More specifically, even though individuals construct their own meanings and understandings of phenomenon, the process of doing so is within the context of the social learning environment (Treagust et al., 1996). From a constructivist standpoint ideas are not transferred between knowers. Instead learners construct their own meanings from information and experiences and understandings are dependent upon pre-existing conceptions.

Conceptual Framework

Teaching with Insects was designed from a social constructivist and conceptual change orientation to learning. Social constructivism is a form of constructivism that is derived primarily from Vygotsky (Davydov, 1995; Moll, 1992; Wertsch, 1991). According to Vygotsky, the construction of knowledge occurs through interaction with the social world and cognitive development occurs by means of the interaction between the individual and the social environment (Vadeboncoeur, 1997). Social constructivists, therefore, do not focus primarily on the individual, rather they view the social context as instrumental in the learning process (Richardson, 1997). Because learning cannot be separated from action, knowledge is constructed rather than passively received separate from the individual. Prawat (1992), however, warns of “naïve constructivism” and expresses concern over the tendency to equate activity with learning. In his view, this serves as an impediment to the constructivist view of teaching and learning.

Regardless of the interpretation, the constructivist view allows us to explain that student’s pre-instructional conceptions guide or even determine their sense-making process (Treagust et al., 1996). Therefore, from a constructivist perspective if individuals construct their own knowledge, then learning by construction implies a change in prior knowledge (Cobern, 1993), where change can mean replacement, addition, or modification of extant knowledge. Learning involving change is the basis of the conceptual change model of learning (Posner et al., 1982).

The conceptual change model describes learning as a process by which a person changes his or her conceptions by adding new, restructuring existing, or exchanging existing conceptions for new conceptions (Hewson, 1996). The key factor for learning is the status (Hewson, 1981) that the new and existing conceptions have for the learner. In order for new knowledge to be constructed, the learner needs to become dissatisfied with their pre-existing conceptions and feel it is necessary to reconcile the new information with their existing conceptions. In order for that reconciliation to occur, the new concept must be seen as intelligible, plausible and fruitful (Hewson, 1981; Posner et al., 1982). More specifically, in order for new conceptions to be reconciled with pre-existing conceptions, the concept must first be intelligible or understandable to the learner. Next, the learner must see the new concept as plausible or believable and consistent with other conceptions that are already accepted. Finally, the new conception should be viewed as fruitful, or assist the learner to achieve something of value (i.e., being able to address a previously unsolvable problem). Thus, the new conception should be held in a higher regard. The extent to which the conception meets these conditions is termed the status of a person's conception (Hewson, 1996).

It is important to note that the conceptual change approach to teaching and learning is a programmatic orientation within Science Education at this university. It is intended that all courses reflect this model of teaching and learning as part of a larger, coherent science teacher education program. Prospective teachers take the required subject matter courses as a pre-requisite to the teaching and learning courses. A goal of the Science Education Program is that prospective teachers have multiple opportunities to be engaged as learners in environments that support a common approach to learning science. With this program model, subject matter courses are consistent with the larger message of supporting children's science learning. Teaching with Insects was designed as one component of the Science Education Program.

Course Activities

There were three major components of the course. One focused on learning about scientific inquiry, one focused on science inquiry in the elementary classroom, and the third emphasized developing a community of learners. First, prospective teachers engaged in a long-term inquiry investigation using the insects they researched during Introduction to Entomology.

It was hoped they would find the learning experience intelligible even though many had never previously experienced learning in this way. The second major assignment was a teaching project that provided prospective teachers with experience teaching inquiry-based science to elementary children. This opportunity to teach children was intended to support conceptual change with regard to prospective teachers' conceptions of science teaching and learning. It was hoped that prospective teachers would find teaching inquiry-based science plausible and as a result, would embrace a conceptual rather than activity-based approach to science teaching and learning. A third component of the course, peer collaboration, feedback and discussion, was intended to support a social constructivist view of learning and transform the class into a community of learners. Not only did the prospective teachers work within small groups but they also regularly shared their ideas and provided feedback across groups.

The long-term investigation project was carefully introduced and developed over several weeks. Prospective teachers worked in small groups of four and each received a live culture. Each individual identified the environmental and dietary requirements of the insect or arthropod and maintained their own culture. Individuals within each group were given the same culture, but cultures varied among groups. The four cultures included three types of insects and one non-insect arthropod. The insects included mealworms (Order Coleoptera), Madagascar hissing cockroaches (Order Blattodea), crickets (Order Orthoptera). The non-insect cultures were sowbugs (Order Isopoda). Even though sowbugs are not insects, they were an appropriate selection because non-insect arthropods were addressed in the core course, Introduction to Entomology. Moreover, Isopods are common in our environment and familiar to most children. The cultures were purposefully selected due to their ease of handling and the ways in which they represent life science concepts such as life cycles and metamorphosis, behavior, and adaptations. In all cases, the insects or Isopods had observable characteristics and behaviors that naturally invite questions that can be tested through simple investigations. It was with the cultures that the prospective teachers designed and conducted their extended science investigation.

Aspects of engaging in science investigations were a focus of the class sessions. Each day a particular aspect of experimental design was addressed. For example, class topics consisted of making observations, asking testable questions, designing experiments that would inform the questions, controlling variables, collecting and interpreting data, and developing data-

based explanations. The investigations designed by the prospective teachers were conducted throughout the 8-weeks of the course. Each group of prospective teachers developed an original question that could be tested experimentally. All data were organized and interpreted in order to develop evidence-based explanations. The investigations and the course culminated in research presentations to peers and instructors. The presentations included a discussion of the experimental questions, methods, findings and explanations, and research implications.

The immersion the prospective teachers into an inquiry-based environment that enabled them to be successful learners of science was intended to support the development of appropriate and robust understandings of scientific inquiry. Even though the inquiry project was highly self-directed (NRC, 2000), the experiences associated with the course were carefully facilitated and supported. There were many in-class work sessions during which prospective teachers conducted trials of their experiments and organized data. This time was important for sharing ideas, asking questions, and seeking feedback from peers and course instructors. These work sessions provided prospective teachers with opportunities to examine their own thinking and share experiences with peers. The interactions also enabled prospective teachers to co-construct and socially negotiate new understandings about their investigations and cultures. The class discussions were also a central means of sharing of ideas both within and across groups. As problems were encountered, such as controlling variables or representing data in meaningful ways, the prospective teachers explored solutions as a community of learners. While instructors provided support, guidance and feedback, there were no instances in which the prospective teachers were told how to proceed with the investigation. They were encouraged to try out and learn from their own ideas. A secondary goal of Teaching with Insects was to promote a conceptual approach to science teaching and learning in contrast to an activity-based approach. An activity-driven approach often reflects a collection of pre-packaged activities that are hands-on, but often disconnected from one another. This approach does not model an inquiry-based approach to science nor does it facilitate children's conceptual understandings (Moscovici & Nelson, 1998).

The second major project associated with the course was an inquiry-based teaching project. Like the long-term investigation, it was introduced and gradually developed over time. Because the prospective teachers were at various stages of the teacher education program, the

interactions with children were guided and carefully scaffolded with regard to the experiences with children. The prospective teachers gradually advanced through three phases of development in learning to support children's science learning. In the first phase, prospective teachers engaged as learners in science activities that were designed for children. Course instructors facilitated activities that addressed particular concepts relating to insect adaptations. After experiencing the activity, prospective teachers and course instructors discussed features of the lesson and the ways in which it supported learning about insect adaptations.

The second phase of learning to teach brought children to the university and engaged them in the activities modeled in phase one. Course instructors again facilitated the activities and this time the prospective teachers partnered with and observed the children. As they interacted with the children they noted behaviors and reactions, as well as the children's ideas and thinking about insects. Following this experience, the prospective teachers discussed what they had seen and heard from the children. As a group, they described and processed the children's ideas, talk, and the nature of their interactions during the activities.

In the final phase, the prospective teachers assumed the role of the teachers. As a group, they designed inquiry-based activities that applied a conceptual approach to science learning and teaching. For this project, they modified their long-term investigation into an inquiry-based mini-experiment that they implemented with children. The lessons developed by prospective teachers followed an approach where children predicted, observed, and explained particular insect-related phenomena. Lesson construction was assisted through a plan-teach-reflect model of lesson development.

When planning the lessons, prospective teachers used the *National Science Education Standards* (NRC, 1996) as a guide for identifying appropriate concepts associated with their extended investigations. In their small groups, they developed age appropriate lesson plans that were first taught to peers. As a result of the peer-teach, prospective teachers both gave and received feedback that was used to revise the activities. Finally, the lessons were taught to children during a Hands-On Bugs day that was open to the public and sponsored by the Entomology Department.

Hands-On Bugs had an open format where children and parents cycled through multiple learning stations. While there was no control over the number and ages of children, organization

was maintained by cycling the participants as groups whenever possible. Prospective teachers shared all the responsibilities for the activities within their group and had multiple opportunities to teach children of all ages. As with all their prior experiences with children, Hands-On Bugs culminated with a large group discussion during which the prospective teachers shared their experiences. The discussions focused on the children's ideas, talk and actions regarding the concepts and the experience, as well as the implications for supporting children's science learning in school. In addition, all the activities were videotaped and used as tool to facilitate reflection on the experience.

In addition to the course activities that supported the investigation and teaching projects, there were many in-class discussions about science, children and learning. While the focus of most class sessions was on the investigations and aspects of scientific research, they often culminated with a connection to education and/or children's science learning. For example, the class session devoted to the development of testable questions from detailed observations turned its focus in the end to children's questions. More specifically, there was a discussion on how teachers can support children's questioning through productive questioning strategies. In addition, the reading assignments associated with testable questions focused on questioning techniques designed to elicit children's ideas (Harlen, 1985).

Throughout the course there were multiple opportunities to examine a variety of resources regarding both research and teaching. The prospective teachers explored and used the *National Science Education Standards* (NRC, 1996) to consider the life science and science inquiry concepts appropriate for elementary school children. In addition, a variety of resources were available within the classroom, ranging from activity guides to field guides. Prospective teachers were also encouraged to use the Internet as a source of additional ideas and information.

The role of reflection in learning was also prominent throughout the course. Prospective teachers regularly reflected on their own science learning through reflective writings. Another important feature of the class sessions were group discussions that encouraged questions and the sharing of ideas about science and science teaching and learning. Prospective teachers also participated in weekly electronic threaded discussions where they responded to questions posed by instructors. In this forum, course instructors monitored small group discussions, asked probing questions to extend current thinking about science teaching and learning, and provided

necessary ongoing feedback. The prospective teachers were encouraged to use the electronic environment to raise important questions they encountered while outside of class. Discussion was also used as a tool for reflection on particular course experiences. Each of the major assignments culminated in a group discussion that processed the experience. In these discussions, the prospective teachers shared their ideas and reactions with peers in addition to writing and reflecting individually. While the class discussions were designed to probe their thinking and support reflection, the written reflections were part of course assessment.

Assessment

Assessment in the course focused primarily on the three major components: the extended investigation, the inquiry-based teaching project, and participation in discussions and classroom contributions. The investigation project had both an oral and written component. Prospective teachers prepared a research report that included their research questions, background information, methodology, findings and explanations, and new questions for research. Using PowerPoint™, they presented their research to peers and instructors at the end of the course. All prospective teachers were expected to participate in the presentations as well as ask thoughtful questions during peer presentations. The Hands-On Bugs experience was assessed on the plan-teach-reflect components. Lesson plans were graded as a group project and because the prospective teachers were just beginning their teacher preparation, assessment of the teaching was based on participation, rather than quality of the teaching itself. All post-teaching reflections were submitted and graded individually.

Because of the social constructivist influence on the design of the course, class participation was an integral part of the learning environment. Discussion was a primary means of introducing and exploring issues that supported developing understandings of concepts. It provided prospective teachers with the opportunity to interact and socially negotiate new understandings of the concepts. To encourage this type of interaction, they were expected to make thoughtful and substantive contributions both in class and in the electronic discussions. While the prospective teachers were not assessed on what they said in the discussions, they did receive a participation grade based upon regular contribution.

The Evolution of Teaching with Insects

Teaching with Insects was first taught during the spring of 1999. As part of an ongoing research agenda, the course has been actively studied with regard to prospective teacher learning about scientific inquiry and science inquiry in the elementary classroom. As a result of research findings, the course has gradually been modified and enhanced with technology tools to support scientific inquiry.

Research on Understandings of Scientific Inquiry

Research on the experiences associated with this course (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002) suggests carefully crafted experiences engaging prospective teachers in science inquiry can support the development of more appropriate understandings of science and school science. More specifically, engaging in an original science investigation assisted prospective teachers in becoming more attentive to the processes of science and developing more elaborated and data-driven explanations of how science is practiced. In addition, when prospective teachers struggled with particular aspects of their investigations, those aspects became foci of change in their thinking about science and doing science. For example, when prospective teachers struggled to interpret and understand data collected in from the experiment, the central role of data in scientific experiments emerged as an important component of their understandings of research in science. However, findings also revealed that prospective teachers were likely to experience difficulties with various aspects of the experimental design, as well as the explanation building process (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002). In response, an intervention was developed using *Progress Portfolio*, a tool designed to promote reflective inquiry during learning in resource/data-rich environments (Loh et al., 1998).

Using Progress Portfolio to Support Scientific Inquiry

During 1999 and 2000 the initial changes to Teaching with Insects reflected minor revisions to reading and homework assignments. The support the extended investigations, prospective teachers were provided with more structured guidelines and the role of evidence and explanation was addressed explicitly in class activities and discussions. Then, in the Spring 2001 semester, *Progress Portfolio* was incorporated into the course. All other aspects of the course

remained consistent with the previous semesters, including the instructor. The *Progress Portfolio* tool was designed to promote reflective inquiry during learning in resource/data-rich environments (Kyza, Golan, Reiser, & Edelson, 2002; Loh et al., 1998). The software is a shareware application and was developed by researchers at Northwestern University. It is a software shell that allows teachers to craft templates that are used by students to guide them through complex tasks. Students build a portfolio that progressively documents the processes through which they engage in and complete tasks. The software enables users to easily navigate between pages in the portfolio. All existing pages are displayed in a left-most frame and simply clicking on an icon launches a page in the right frame. Students can use the pages created by the instructor or choose to develop their own. In addition, they can label, re-order, or group the pages in any way that makes sense to them (Kyza et al., 2002). General features of the software include a “data cam” tool that enables learners to toggle between software applications and capture images for insertion into the portfolio. The software also includes “sticky notes”, which are similar to electronic post-it notes that enable teachers to provide feedback and students to label purposes and thinking processes.

The technology scaffolds provided by the tool were explicitly designed to help guide the learners to understand the goals of the task they are working with and find support both in making sense of the content and acquiring general inquiry skills (Kyza et al., 2002). Specifically, Kyza and colleagues (2002) describe the scaffolds associated with *Progress Portfolio* as belonging to four categories: 1) Scaffolds, like data cam, that enable the learner to move smoothly between two software environments, 2) Scaffolds, like the page templates, that enable learners to organize information in ways that are meaningful to them, 3) Scaffolds, like sticky notes and text boxes, that guide and facilitate articulation, and 4) Scaffolds that support management, searching and manipulation of the information stored in *Progress Portfolio*.

In the context of this course, the *Progress Portfolio* environment was tailored to assist students with their experimental design, the management and storage of their information, and the organization and articulation of their experimental findings. In particular, the template was designed to scaffold learners in making connections across elements of the investigation, reflect on what they were learning in light of what they already knew about the insects, and develop of evidence-based explanations. For example, the template included a *Research Design* page that

asked prospective teachers to identify their experimental design as well as explain how the design supported the research questions. On a *Results* page, they were prompted to discuss what they were learning from their investigations in light of what they already knew about their insect, and on an *Explanations* page, they used their data to generate a series of claims about their insects. Each claim asked for supporting evidence and an associated justification statement of how the evidence supported the claim.

Continued research on this course (Avraamidou et al., 2002; Haefner et al., 2002) indicated that the technology scaffolds provided by *Progress Portfolio* assisted prospective elementary teachers in developing evidence-based explanations that were grounded in data. *Progress Portfolio* was designed to provide a workspace for learners to document their questions and understandings, manage their data and analyses, and communicate about and reflect upon their investigation (Loh et al., 1998). In this course, the tool was useful for structuring and tracking the progress of prospective elementary teachers as they engaged in an original inquiry investigation. Moreover it supported reflection on what the prospective teachers were learning from the experiments in light of what they knew about insects. Among the benefits was that the template made important aspects of conducting investigations explicit, including the role of scientific explanations. A strength of *Progress Portfolio* is the ability to focus students on the typically invisible aspects of the inquiry process and enable them to track of their progress as they engage in long-term investigations (Loh et al., 1997; Loh et al., 1998). For many of the prospective teachers in this course, this was their first experience engaging in an original science investigation and the structure provided by *Progress Portfolio* supported the coherence of their experimental design and the management of their data. This is encouraging given previous research on the experiences associated with this particular course without the use of *Progress Portfolio* revealed instances in which prospective teachers struggled to manage large amounts of data and interpret the experimental findings (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002).

Research on Understandings of Science Inquiry in the Elementary Classroom

Finally, although it was not the central focus of the course, the research associated with Teaching with Insects revealed interesting changes in the area of prospective elementary teachers' understandings of science teaching and learning. Specifically, as prospective teachers came to place a greater emphasis on questions, observations, and experimentation as fundamental aspects of doing science, they became more accepting of approaches to teaching science that encourage children's questions about science phenomena. Inherent in the student-generated, question-driven approach to science teaching and learning, is the recognition that children possess a variety of ideas about science concepts – some of which are more consistent with scientific views than others. Although the prospective teachers by no means developed an in-depth understanding of the role of children's prior knowledge in learning, they did begin to recognize that those ideas might be useful to science instruction. Research has suggested that opportunities to teach children have the potential to assist prospective teachers in developing a greater awareness of children's science experiences (Gustafson & Rowell, 1995) and enable them to accept the significance of students' ideas in teaching (Meyer et al., 1999). Teaching with Insects made explicit connections to children's ideas about science concepts. In particular, there were multiple opportunities for prospective teachers to discuss and reflect upon children's thinking about insects in light of their own science experiences. An interesting and perhaps powerful part of the course was that the prospective teachers in this study engaged in some of the same science learning experiences as the children with which they interacted. As a result, they saw close connections between the children's ideas and explanations, and their own.

Conclusion

The research findings associated with Teaching with Insects are encouraging with respect to the development of teachers who are prepared to teach in the vision of current science education reform. Specially developed science content courses, such as the one described here, can assist prospective teachers' in developing more appropriate understandings of science and science inquiry (Haefner, 2001; Haefner & Zemba-Saul, 2001, 2002). More specifically, while a number of persistent issues were reported, research in this context indicates that carefully crafted experiences as part of content courses can influence prospective teachers' thinking about

science and doing science. In addition, technology tools such as *Progress Portfolio* can be used to support reflection and the development of evidence-based explanations (Haefner et al., 2002).

Carefully crafted opportunities interacting with children as part of science content courses can also influence the way prospective teachers think about school science and children's ideas. Through experiences such as the ones described here, science teaching became less about imparting knowledge and more about providing opportunities for children to ask questions about science phenomena. Engaging with scientific questions seemed to be an avenue by which prospective teachers came to consider how children's questions could be useful when developing science lessons. As a result, encouraging children's questions made aspects of inquiry-oriented pedagogy accessible to prospective elementary teachers.

While prospective teachers need experiences learning science and science inquiry in meaningful ways, studies on this course reveal that concurrent opportunities to translate science understandings for the purposes of teaching children may facilitate the development of pedagogy for supporting children's learning. While the authors do not believe that this one, 8-week experience at the beginning of the teacher preparation program had a long-term influence on the teaching practices of the prospective teachers, it does offer a glimpse into the kinds of experiences that could contribute to more robust and appropriate understandings of scientific inquiry and science inquiry in elementary classrooms. With multiple opportunities to learn about science inquiry as part of their general education coursework, prospective teachers can develop richer understandings of science subject matter and science teaching and learning.

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