Journal of Elementary Science Education, Vol. 16, No. 1 (Spring 2004), pp. 9-20.

Scholarship in Science Education

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Science education reform efforts set expectations for K-12 education to produce scientifically literate individuals. Implicit in this reform is the need for preservice teachers to be engaged in learning that builds their knowledge, understanding, and ability toward good science teaching. In this paper, I describe some of the experiences in science education for preservice elementary teachers and their reactions to the activities as indicated by their responses on an exit survey. The preservice teachers assess the effectiveness of each activity based on their expectations of the course, and the extent to which the activities are reproducible in elementary classrooms.

Toward Scholarship in Science Education for Elementary Teachers

It is every science educator's dream that the next group of students enrolled in the science education course would have a basic understanding of science and a positive belief that they can learn science. The harsh reality is that too many elementary preservice teachers enter the preservice education program with insufficient science knowledge (Gess-Newsome, 1999) and low levels of science self-efficacy (Raizen & Michelsohn, 1994). What then do we do when students enroll in science education courses for elementary teachers? How do we address the needs of the preservice teachers to construct their own understanding of science while developing knowledge of pedagogy and appropriate practice? In this paper, I describe some of the experiences in the course, Teaching Science in the Inclusive Classroom. I include the philosophies that guide how the science education curriculum is developed and report on the students' reactions to the teaching and learning activities as indicated by their responses to a survey administered at the end of the semester.

Since the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1993), state and national agencies have embraced reform efforts aimed at raising the achievement level of all students. By setting standards, and by changing the way science is taught, these reform efforts set clear expectations for K-12 education to produce scientifically literate adults (AAAS, 1993; NRC, 1996). Implicit in the reform efforts is the need for preservice teachers to be engaged in active learning that builds their knowledge, understanding, and ability to facilitate effective science teaching practices.

In recent years, science has become an established subject in the elementary school curriculum. Such establishment was strengthened by the National Science Education Standards' vision for teaching and learning science (NRC, 1996) and supported by state-mandated curricula. Even with these standards, however, it is often true that science is not given enough attention in the elementary setting. Consequently, science teacher educators, recognizing that teachers are central to the success of science reforms (NRC, 1996; Rutherford & Ahlgren, 1990; Yager, 1992), have begun to examine their practices within science teacher education. As a science teacher educator, one of my concerns is the selection and determination of

appropriate teaching and learning experiences. This has implications for the nature of the science education program and the preparedness of the preservice teachers.

The Mathematics, Science, and Technology Semester

In the seventh semester of the University of Florida teacher education program, students are enrolled in three methods courses. These are science education, mathematics education, and educational technology along with other courses outside the College of Education. This semester is referred to as the Math, Science, and Technology (MST) block. A unique feature of this semester is that it involves a level of integration across the subject areas while focusing on pedagogy and content within the individual subjects. Integrating mathematics and science and the use of technology as a "worthwhile tool" to facilitate such interactions are important components of the semester. An enduring argument for this integration is that a teacher in an inclusive classroom has difficulty finding time to do everything that needs to be done, and science, in many cases is the subject that gets neglected (Howe & Jones, 1998). Such integration also satisfies the current reform movement in mathematics and science education as stipulated by their governing councils: the National Council of Teachers of Mathematics (NCTM) (1989) and the NRC (1996). Both councils identify mathematics as playing a central role in the learning of science as students gather, represent, and analyze numerical data to answer scientific questions.

During the first two weeks of the semester, the science, mathematics, and educational technology instructors collaboratively plan and implement a series of workshops to introduce the entire five cohorts of the MST block to the concept of interdisciplinary teaching. In the workshop, theories and rationale for integration are shared and explained. Using various models of integration, the instructors work with the students to develop curriculum which integrates mathematics, science, and technology while considering other subjects such as language arts, social studies, and the arts. In the science methods course, an immediate follow-up to the workshop is the modeling of a fourth-grade integrated lesson called "Seeds." Over the course of the semester, students are required to complete two integrative assignments: Microteaching and Self-Reflection and Nontraditional Field Experiences. The points received from these assignments count toward a fraction of their grades in all three courses.

The Science Education Program

The standards recently adopted in science propose decreased emphasis on memorization and drill exercises and greater emphasis on inquiry, meaningful learning, and the development of critical thinking skills. Guided by these standards, the groundwork has been laid for new classroom approaches and teaching strategies that encourage students to become active learners. One of the goals of the science education course is the provision of opportunities for the preservice teachers to construct such a vision of science teaching and learning and assist them in projecting themselves into that vision. Using hands-on/minds-on science as the context, the preservice teachers are involved in activities to develop strategies and techniques applicable to teaching and learning science in the inclusive elementary classroom. In order to enhance pedagogy, science content knowledge, and the elementary classroom context, the science education course addresses four primary themes: (1) nature of science, (2) assessment, (3) issues in teaching and learning science in elementary classrooms, and (4) interdisciplinary teaching for the inclusive

elementary classroom. In-class activities are supported by assigned readings from the textbook, *Methods for Teaching Science as Inquiry* (Carin & Bass, 2001), and from selected journal articles. A number of assignments are specifically developed to coincide with each of the primary areas. These include microteaching; development of teaching materials, inclusive of lesson plans; content-based conceptual papers; and science picture books. These will be discussed in later sections of this paper.

The preservice teachers are enrolled in at least one science course from the College of Liberal Arts and Sciences at the same time that they are enrolled in the science education course. Some of these courses are specifically developed for preservice elementary teachers. At the start of the semester, in collaboration with the science content instructor, selected science content knowledge is rearranged and sequenced to coincide and become part of the knowledge base in the science education course. For example, in their life science course, the students learn about life cycles of certain animals. In the science education course, students construct concept maps on life cycles and develop project-based learning experiences for elementary children to explore life cycles. This collaboration, while time consuming for the instructors, allows the students to learn processes and habits of mind of science while exploring pedagogy suitable for teaching science to elementary children. At the same time, students' experiences become more enriched as they become involved in well-rounded scientific experiences. These experiences facilitate meaningful learning of pedagogical knowledge and skills while cultivating a more robust understanding of scientific processes and concepts.

In another activity, students choose a topic from their science content course taken in the College of Arts and Sciences and write a conceptual paper indicating an understanding of the content above high school level. In the second phase, they develop a lesson plan for a named grade. Along with the plan, using their knowledge of children's literature, the preservice teachers create picture books that present scientific concepts in meaningful, age appropriate and understandable form for elementary children. In creating their own science picture books, the preservice teachers learn to develop familiarity and ease in understanding how to first learn science concepts and then teach these concepts to elementary children. The students' conceptual papers and picture books allow them to document and represent the science content learned. This requires the skills of comprehension and synthesis while thinking about key ideas and valid science knowledge. In addition, this activity provides the instructor with the opportunity to identify and challenge some of the students' subtle misconceptions. For example, in a picture book about living things, a student wrote that living things breathe in oxygen and breathe out carbon dioxide. This was noted by the instructor and led to a lesson on the composition of air and the process of breathing to confront and challenge the misconception identified in the picture book.

Preparing for Inclusion in Elementary Science

One element of the teacher education mission is to prepare teachers who are sensitive to diversity (Conn, 2001; Lee, 2003; Palincsar, Magnusson, & Collins, 2001; Watson & Houtz, 2002). The processes of teaching that underscore these goals are accompanied by adaptations to meet the needs of each student in the inclusive classroom (Stefanich, 2003); however, a constant challenge that science educators face has been how to guide preservice teachers from mere sensitivity to actions in the teaching of science to ALL children (Conn, 2001). In the course, an in-class activity provides the opportunity to address this challenge. Guided by the assigned text, the preservice teachers investigate the characteristics of named special needs. In groups,

the students discuss each of the needs such as gifted, varying exceptionalities, and students who speak English as a second language. They select one of the special needs, explore specific adaptations, and use the information as the basis for the next stage in the teaching and learning activity. The activity continues as we select curricular standards, and their accompanying benchmarks, and as we identify a lesson topic for a named grade. Each group then develops an activity suitable for the grade chosen and adapt it for the particular special need. During the whole class discussion, the groups share their activity, the issues considered, and the rationale for the direction taken in developing the activities. Last spring, one student at the end of her presentation asked an important question: "Why do we make lesson plans with one teaching activity if we have to incorporate the needs of all children?" Did her question reveal antisentiments for lesson planning? Or was it a sudden awareness that in the inclusive classroom, teachers need to vary teaching strategies and adapt activities to facilitate science learning for all children?

Facilitating inclusion is also fostered through the use of case studies and narratives. Case analyses provide a mechanism for students to explore the complexities of classrooms and to make connections between the university coursework and possibilities in real classrooms. These case studies and narratives are chosen from journal articles and educational videos that accompany the methods text. These narratives present pedagogically sound classroom practices and age and developmentally appropriate science content. The narratives afford reflection and critical analysis of life in the classroom. The students make reasoned decisions by considering a variety of information in the context of teaching and learning, which are not often predictable. As students watch the videos and read and analyze the text, they call on their own ways of making sense of the world and, in these moments, it is possible for them to consider biases, personal beliefs, and their own histories. In the discussions that follow the reading of the cases, issues of perspective and cultural understandings are raised. Thus, narratives not only provide an opportunity for students to reflect on classrooms and students but also to consider how their own perspectives may shape teaching and learning.

Planning to Teach

A question preservice teachers constantly ask in our science education course is, "How do we decide at what level to plan our lesson?" Interpreted another way, the question asks, "How do we choose the level of content to incorporate in our lesson plans while considering the cognitive and developmental levels of all the students in the classroom?" To effectively plan science lessons, the preservice teachers not only need to know the content and be familiar with mandated standards, but they also must be aware of children's experiences and their preconceptions about the science content knowledge.

One assignment in exploring children's knowledge requires the preservice teachers to interview ten elementary children and elicit their knowledge about specific science content. These concepts are selected from the state's mandated curriculum and include energy, electricity, force, magnetism, weather, and machines. With a partner, the preservice teachers investigate the topic to further their understanding until they feel comfortable enough to develop valid questions for the chosen grade level. The preservice teachers use various strategies to determine the children's level of science knowledge and possible alternative constructions. The purpose is to elicit the knowledge the children have about the concept, identify gaps in their understanding, and bring to the fore any existing misconceptions.

The preservice teachers developed questions, used oral interviews requiring the children to talk freely about their knowledge on the topics chosen, and, in some cases, incorporated written responses. In such instances, the children were instructed to write or draw their responses but were cautioned that the exercise was in no way a test for grading purposes. Some preservice teachers used performance tasks in which the students were given materials and instructions. The children were observed and questioned during the process as they carried out the tasks. These conversations were recorded and carefully analyzed for misconceptions and alternative constructions. The data collected from the interactions with the children were then used as the basis for developing lesson plans for the grade level. A disadvantage of this assignment is that the lessons are not implemented, and so the preservice teachers cannot evaluate the effectiveness of their plans.

Microteaching: Exploring Integration

In the MST block, we adapt microteaching as an instructional strategy to facilitate the students' selection of appropriate content and application of teaching skills. The microteaching also creates a context in which deliberate attempts are made to integrate technology in science and mathematics lessons and to encourage reflection on the experiences. During microteaching, the preservice teachers plan and practice the instructional strategies learned in the methods courses during the semester. They develop and teach a 30-minute lesson that integrates math, science, and technology. The lesson is developed for a grade level of their choice and is correlated to the state's curriculum standards. The preservice teachers are responsible for all facets of the teaching and learning activities. They submit a written lesson plan to the instructors and make the necessary arrangements to acquire the technologies needed on the day of their teaching session. These lessons are taught to their peers and observed by the math, science, and technology instructors. The instructors provide feedback on the lesson development (from introduction to closure), use of content knowledge, delivery of and response to questions, implementation of classroom organization strategies, and the appropriate application and integration of the technology. The feedback from each instructor is compiled into one document, and students receive a common grade applicable to the three courses in the MST block.

An extension to the microteaching activity requires each student to reflect on both the planning and teaching processes and to suggest alternative actions toward improvement. The Self-Reflection Profile is a document developed for recording segments of the lesson plans along with related observations and subsequent reflections. The lesson objectives, science content, teaching learning activities, and tasks for summative assessment are recorded in the first column. After teaching, the observations and reflections are documented in the corresponding columns. An open-ended section of the Self-Reflection Profile requires responses to the following questions:

- If you were to teach this lesson again, what would you do differently? What would you do the same? Why?
- If you had done this activity with real elementary students, what differences would you have encountered in teaching the activity?
- What changes would you now need to make to the lesson to effectively accommodate the elementary children?

The students' responses to these questions and their overall reflections form the basis for post-microteaching discussions among their peers and with their instructors. The Self-Reflection Profile became a very effective tool for initiating reflection among the preservice teachers. It allowed them to note specific aspects of planning and action and to critically comment on these areas.

Students' Reactions

At the end of the semester, a survey is administered that requires the students to rate each of the major experiences in the science education course. The rating is on a scale from one to five, where five is superb and one is weak (see Appendix). The students also provide comments or justifications for the rating given to each activity.

Table 1 shows the list of the major teaching and learning activities along with their mean rating. Analysis of the survey done in spring 2002 revealed that students appreciated the in-class, hands-on, minds-on activities. This activity along with implementing microteaching were the two that had a mean of 5.0. For the in-class lab experiences, a common comment was that they provided science activities that could be reproduced in the elementary classrooms. The following comment by a student captured the essence of the class's feelings: "The in-class lab activities can be used directly in our teaching or they can be altered to match our students." Another student wrote, "Doing the activities in the class showed me how they can be done with children." And yet another student stated, "Now I have tons of activities to use in my class." These comments were consistent with the goals previously articulated by the preservice teachers at the start of the semester.

Table 1
Mean Rating for Each Activity

Teaching/Learning Activities	Mean
Assignment 1 – Learning the science content and writing the conceptual understanding	3.1
Integrating science and literature	3.6
Investigating elementary students' misconceptions	2.5
In-class science lab activities	5.0
MST integrated workshop	4.8
Collaborating with Life Science course	4.7
Nontraditional field experience	2.9
Journaling about the field experience	3.0
Observing the elementary science classroom	4.1
Reading the assigned textbook	2.6
Reading journal articles	2.5
In-class lecture/discussion	3.8
Planning for microteaching	3.9
Implementing microteaching	5.0

N = 60

Planning for and implementing the microteaching were rated favorably. They had a mean of 3.9 and 5.0. The highlight of the students' comments noted that the planning took more time and effort than the teaching. Both allowed them to go through the steps of developing and implementing a lesson. The students thought the microteaching was a good experience for them and noted that it helped them

to develop a level of confidence in being able to teach a science topic. One of the students wrote, "I never believed that I would teach a science lesson, but after the microteaching, I know I can."

The observations of the elementary science classrooms, and the collaboration within the MST block of courses and between the science content courses were given high ratings. These activities had a mean of 4.1, 4.8, and 4.7, respectively. The two elementary classrooms were selected for observations because of the nature of their science programs. Science was taught at least twice per week in both classes. Comments written by the students indicated that in both classrooms they observed some of the strategies that were being developed in the science education course. Some of these strategies were that children were doing science in groups and working with objects such as batteries and wires. These observations served to solidify the notion for them that children can be involved in the doing of science. For both collaborative sets of activities, the preservice teachers expressed surprise that instructors had conversations about issues such as pedagogy and assessment. They reported an added level of comfort because their instructors were collaborating toward their learning, to the extent that on a few occasions, one science content instructor from Liberal Arts and Sciences was present at their microteaching. In making the point for both collaborative activities, a student wrote in bold letters, "The Professors really spoke to each other."

The assigned readings from the text and from selected journals along with exploring children's misconceptions were ranked the lowest. They had a mean of 2.6, 2.5, and 2.5, respectively. The majority of students stated that they benefited from the other activities without the readings, and they considered the readings to be busy work. Sixteen percent of the students gave the readings a rating of 4.0, and they indicated that the readings complemented the in-class teaching activities. Quite noticeably, these two activities were not given a rating of 5.0. The feedback on the assignment, Children's Misconceptions, indicated that most of the preservice teachers did not see this as a worthwhile assignment. They wrote, "Teachers do not have the time to set up special activities to find out children's misconceptions," or, "Teachers need the time to teach." Three students did give this assignment a rating of 5.0, however. In general, these three saw the assignment as important for planning, but two stated that it was unrealistic for classroom teachers.

Discussion

During the MST block, efforts are devoted to developing competence and confidence in the preservice teachers. This competence involves a level of understanding of the subject matter and of how children learn, and a conceptual framework of teaching that can be used to create learning experiences. Consistent with beliefs about how children learn science, the nature of science, and the importance of science for the next generation, this science education seeks to introduce preservice teachers to the scholarship of science education. The course tackles the important task of selecting experiences that best facilitate preservice teachers' learning of science content knowledge, and appropriate pedagogy worthy of the scholarship of elementary science education. To this end, experiences are provided for the preservice teachers to make sense of classroom observations, to become thinkers about those observations, and to become involved in reflective practice toward continuous improvement of science teaching and learning.

In this paper, I describe the teaching and learning activities that were provided in the science education course. I also report the students' reactions to these

activities as indicated on an exit survey administered at the end of the semester. Analyses suggest that the preservice teachers had varying reactions to each of the activities. These reactions ranged from activities being highly important in facilitating their learning to teach to what was considered "busy work."

In identifying meaningful activities, the students remained unwavering about the fulfilling of their needs. During the first lesson of the semester, students are required to document their expectations of the science education course. All of the students stated that the course should show them how best to teach elementary children, and also provide them with a repertoire of science activities applicable to their future classrooms. Their ratings of the in-class lab activities and the microteaching were consistent with what they considered as being important for their learning to teach science. Clearly the preservice teachers valued these classroom activities and the opportunities to plan and implement science instruction. The responses garnered from these students corroborated findings by Boone (1993) and Lederman, Gess-Newsome, and Latz (1994). They found that teaching skills that make use of pedagogical content knowledge and curricular knowledge such as developing lesson plans were highly valued by preservice teachers. Furthermore, science educators agree that science education or methods courses for preservice teachers should help them build both a pedagogical and curricular knowledge base that will prepare them to translate science content knowledge into experiences for elementary children (Butts, Koballa, & Elliott, 1997; Lederman et al., 1994).

The reactions discussed in this paper have implications for selecting teaching and learning activities for preservice teachers in science education courses. Students assess the effectiveness of each activity based on their perceptions of the elementary classroom, their expectations of the course, and the extent to which the activities are reproducible. Such reproductions seem to be associated with their perceived personal survival and their projected abilities to teach science in their elementary classrooms. The students did not react favorably to the assignment that required them to elicit children's misconceptions. This assignment allowed the preservice teachers to establish potential misconceptions that elementary children hold, become involved in data driven decisions about teaching, and also challenged their own preconceptions. The preservice teachers thought that it was unrealistic to plan and implement large-scale activities to identify children's misconceptions. To enhance the effectiveness of the assignment, science educators could facilitate the preservice teachers making more connections between the activities and the realities in elementary classrooms. In-class discussions following such an assignment should involve the exploration of more realistic approaches.

The paper also highlights the importance that preservice teachers attach to collaboration among university professors. The preservice teachers operate within a context where their learning to teach is impacted by a variety of educators, each making different demands. These expectations, in many cases, are not consistent as they move from one course to another. The level of collaboration among the professors as exemplified in the MST block, and with science professors, was a positive experience for the preservice teachers. The collaborations decreased some of the disparities that students experienced and offered some consistencies within and across the programs. It also facilitated the learning of science content knowledge. The students expressed that concepts introduced in the science content or the science education courses were reenforced in the other. The science education and the related pedagogies, however, allowed for the transformation of the content toward applicability in elementary classrooms.

Overall, the discussion in this paper highlights one effort to introduce elementary preservice teachers to the scholarship of science education. Further research is required to delineate the impact of each activity as to their abilities to teach science. The level of corroboration between the goals of the course and the expressed goals of the preservice teachers is also a potential issue for further exploration. Such research could also include a more systematic observation of the students throughout the semester with a view to understanding the process of learning to teach, and how independently, and together, these activities interact in the process of learning to teach science.

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Appendix

End of Semester Survey

Dear members of SCE 4310 – Spring 2002:

The following survey is designed to help me improve my future planning for and teaching of the course, SCE 4310. I would greatly appreciate your input to help me reflect on the experiences that were provided for you in the course during this semester.

Thanks.

Survey

The following list contains all the major experiences (teaching, learning, and assessment) that we were involved in during the science education course, SCE 4310. I want you to indicate your feelings about each of the activities as you experienced them over the semester. Circle the number that best communicates your feelings on the scale from 1-5 in terms of its enhancing your learning to teach science: 5 = superb, 4 = very good, 3 = good, 2 = fair, and 1 = weak. You may refer to your journals.

Teaching/Learning Activities	Rating					Notes/Comments
Assignment 1 – Learning the science content and writing the conceptual understanding	1	2	3	4	5	
Integrating science and literature	1	2	3	4	5	
Investigating elementary students' misconceptions	1	2	3	4	5	
In-class science lab activities	1	2	3	4	5	
MST integrated workshop	1	2	3	4	5	
Collaborating with Life Science course	1	2	3	4	5	
Nontraditional field experience	1	2	3	4	5	
Journaling about the field experience	1	2	3	4	5	
Observing the elementary science classroom	1	2	3	4	5	
Reading the assigned textbook	1	2	3	4	5	
Reading journal articles	1	2	3	4	5	
In-class lecture/discussion	1	2	3	4	5	
Planning for microteaching	1	2	3	4	5	
Implementing microteaching	1	2	3	4	5	

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Manuscript accepted December 12, 2003.