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ABSTRACT

The purpose of this research study was to examine the level of elementary education majors' science content knowledge; pedagogical knowledge; and pedagogical content knowledge in order to evaluate the effectiveness of a new teacher preparation program for undergraduate students with a science area of concentration, developed as part of the Quality University Elementary Science Teaching (QUEST) Project at Indiana University. The subjects (N=58) were senior-level elementary education majors and elementary student teachers. Data collection methods included observations, document collection, self-evaluations, interviews, and surveys. The overall findings for the student teachers indicated that the students held their own interpretation of the interdisciplinary nature of science, espoused inquiry without always practicing it, and admitted that they did not know or understand all of the content they were expected to teach at the elementary level. Results indicate that only a few of the student teachers regularly incorporated innovative teaching strategies in their science lessons. An important conclusion concerning pedagogical knowledge was that paper-and-pencil assessments are not sufficient to predict what will actually take place in the classroom. Contains 31 references. (JRH)

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Preservice Elementary Teachers: Their Science Content Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge

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Introduction

Teacher education programs exist to prepare prospective teachers who know what to do in a classroom of children and how to do it effectively. After a few short years of taking a wide variety of content courses followed by a series of teaching methods courses, education majors are expected to have evolved from full-time students to professional educators. Borko and Livingston (1989) refer to this maturation process as developing pedagogical expertise. They recommend that in order to improve, teacher education programs must examine the acquisition of expertise by their students. This expertise involves theoretical knowledge as well as practical knowledge.

Teachers must possess a specialized understanding of the subject matter they are expected to teach in addition to a personal understanding of the content (Wilson, Shulman, & Richert, 1987). Smith and Neale (1989) contend that while science teachers must have correct substantive content knowledge, they must have the ability to translate that knowledge into classroom teaching. This may be especially difficult to achieve with prospective elementary teachers as research continues to reveal that they misunderstand fundamental science concepts and may not reason at the level required for problem solving (Ginns & Watters, 1995). Some research suggests using conceptual change learning techniques to develop the personal content learning of these preservice elementary teachers (Stofflett, 1994; Stofflett & Stoddard, 1994). Stofflett and Stoddard (1994) advise that "if teachers are to use conceptual teaching methods in their own classrooms, they need to learn content and pedagogy through the same conceptually based methods reformers are advocating be used with grade school students."

Doyle (1990) espouses, "Classroom knowledge provides a framework for understanding how classroom systems work and how curriculum can be represented and enacted in these environments." Conceptual teaching must become a part of what Tamir (1991) identifies as personal practical knowledge before a teacher will incorporate that into his or her pedagogical knowledge. Learning to plan lessons and developing successful teaching strategies is a slow process. "Prospective science teachers . . . have few of their own resources and teaching experiences to draw on" (Tippins, Kagan, & Jackson, 1993). The pedagogical knowledge base develops after years of preparation and extensive experience in the classroom (Clermont, Borko, & Krajcik, 1994). Ultimately, preservice elementary teachers must have a considerable knowledge base of each of the sciences (Grossman, Wilson, & Shulman, 1989; Lederman & Latz, 1993), and they must possess a repertoire of pedagogical skills from which they can select the most appropriate way of presenting particular science concepts to children (Magnusson & Krajcik, 1993; McDiarmid, Ball, & Anderson, 1989; Shulman, 1986; Shulman, 1987).

The purpose of this research study was to examine the level of elementary education majors' science content knowledge, pedagogical knowledge, and pedagogical content knowledge. This evaluation is important for determining the effectiveness of a new teacher preparation program for undergraduate students with a science area of concentration, developed as part of the Quality University Elementary Science Teaching (QUEST) Project at Indiana University. In some respects, the science concentration students fit Abell's (1990) description of the elementary science specialist: "a person who has chosen to major in science at the undergraduate level and has received the concomitant professional training for teaching elementary science" (p. 293). Although not science majors, they take additional credit hours of science, work with children in a Saturday Science program, and enroll in a special section of the elementary science methods course.

The last requirement in the science concentration is an interdisciplinary, laboratory capstone course which has a different science discipline basis from year to year. The capstone course is also integrated with an optional middle school field experience. Those students completing the special practicum, under the supervision of mentor teachers prepared through the QUEST Project, receive additional certification for teaching science at the middle school level.

It is of interest to know how students enrolled in the QUEST program differ from students who have areas of concentration other than science. This investigation is an attempt to determine QUEST's effectiveness in preparing elementary teachers with appropriate content knowledge, pedagogical knowledge, and pedagogical content knowledge for the teaching of science.

Research Questions

1. What is the level of preservice elementary science teachers' science content knowledge, pedagogical knowledge, and pedagogical content knowledge prior to student teaching?

2. What differences in the three types of knowledge exist between preservice teachers with the science area of concentration and preservice teachers with other areas of concentration?

3. What changes in science content knowledge, pedagogical knowledge, and pedagogical content knowledge are exhibited by the preservice teachers as they have progressed from the university setting to their student teaching experience?

Methodology

Subjects

The subjects of the first phase of the investigation during the fall semester came from two sources: (a) 24 senior-level elementary education majors (22 female, 2 male) enrolled in *Integrated Science for Elementary Education*, the capstone course for the science area of concentration; and (b) a control group composed of 25 senior-level elementary education majors (21 females, 4 males) with areas of concentration other than science. The subjects of the second phase of the investigation were nine elementary student teachers: six QUEST students (5 female, 1 male) and three (female) nonQUEST students. These nine student teachers were selected from those preservice teachers (a) who had participated in the fall semester data collection, (b) who were willing and able to allow the researchers into their student teaching classrooms during the spring semester, and (c) whose assigned placement was within a reasonable driving distance from the University.

The subjects are similar in that elementary education majors at this large midwestern research university must fulfill a minimum requirement of 12 hours of science content coursework. They must complete an introduction to scientific inquiry course and introductory level courses in biology, geology, and physics. Most students choose to enroll in the biology and physics courses specifically designed for elementary educators. An elementary science methods course is also required. The preservice elementary teachers must complete 18-20 hours of coursework beyond the basic requirements in a content area of concentration of their choice (i.e., fine arts, language arts/humanities, mathematics, science, or social studies). All of these undergraduate students were expected to benefit from changes brought about through the QUEST Project. The scientific inquiry, biology, physics, and methods courses were all revised to include a greater emphasis on conceptual understanding of science content, increased use of an inquiry approach, and the use of technology in data collection and processing,in accordance with the goals of the QUEST Project to improve and update science education at Indiana University.

Twelve of the 24 capstone students participated in a correlated middle school science practicum in local public schools to fulfill the requirements for a middle school science endorsement to the elementary teaching certification. All but one of these students were concurrently enrolled in the senior-level cluster of elementary methods courses and practicum experience, emphasizing the language arts and social studies. Collectively, the capstone students had completed an average of 8.5 college-level science courses prior to the capstone course. The subjects in the control group were enrolled in a separate section of the social studies methods course. Their areas of concentration included fine arts (1), language arts (12), mathematics (1), social studies (10), and no area of concentration (1 student within an old degree program). Students in this group had completed an average of 4.7 science content courses.

Three of the student teachers had completed the capstone course with the additional middle school practicum, three completed the capstone course only, and three were selected from the control group of students with areas of concentration other than science (i.e., language arts, social studies, and no concentration). A brief description of each student teacher and his or her student teaching setting follows.

<u>QUEST Students with Middle School Experience and Their School Settings</u>

<u>Michelle</u> Michelle was assigned to a self-contained second grade class at a K-6 school of 325 students located in a lower socio-economic part of the university city. The school took a traditional approach towards its structure and curriculum. The children in Michelle's class demonstrated a wide range of abilities, including a Down syndrome child and some non-readers.

<u>Beth</u> Beth was assigned to a departmentalized sixth grade where she taught science and math to two classes of 28 students each. The K-6 school had a racially-diverse student population of 550, ranging from lower to upper socio-economic class. To broaden her student teaching experience, Beth was allowed to teach language arts and social studies at the same grade level for the last few weeks of her placement.

Lee was a pre-med major before switching to education and was able to substitute "hard core" science courses for the elementary science courses.

Sharon Sharon was assigned to a sixth grade homeroom class with primary teaching responsibilities for all fifth and sixth grade science classes. The K-6 school of under 300 students, located in a distinctly mixed socio-economic rural area, was influenced by the strong presence of fundamentalist religious denominations in the community, maintaining a traditional approach towards its structure and curriculum. The students in Sharon's classes demonstrated a wide range of abilities and levels of motivation.

QUEST Students-Elementary Only-and Their School Settings

Vickie Vickie was assigned to a K-6 school with approximately 350 students from mostly middle class families and mostly Caucasian ancestry. Vickie was in a self-contained third grade classroom where she taught spelling, math, reading, science, social studies, and health to two alternating classes of 25 students each.

Carla Carla was assigned to a fourth grade class at a K-6 school whose 525 students came from a wide range of socio-economic backgrounds and ability levels, including special education students. The school had some multi-aged classrooms and also a few combined-level classrooms that remained with the same teacher for two years. Carla's class was a self-contained classroom, with a wide ability range among the students.

James James, the only male participant, was assigned to a school of grades 1-5 located in a small town approximately 20 miles from the university campus. The school population was 275 students with a socio-economic range of lower to upper-middle class and mostly Caucasian ancestry. James was in a self-contained third grade classroom where he taught art, computers, music, physical education, reading, science, and social studies to 20 students.

NonQUEST Students and Their Schools Settings

Elaine Elaine was assigned to a self-contained third grade class at the same school as Michelle (see above). Elaine's students demonstrated a wide ability range and included a group of behavior problem children.

Elaine was a non-traditional student: older than her undergraduate peers and married with children. She was working under an old degree program and was not required to declare an area of concentration.

Diana Diana, whose area of concentration was social studies, was assigned to a fourth grade homeroom in a K-6 school with a student population of just under 200 students with a socio-economic range of lower to upper-middle class and mostly Caucasian ancestry. Diana's teaching responsibilities included fourth grade mathematics and social studies, as well as teaching language arts, reading, and science to a combined-level class of 25 fourth, fifth, and sixth graders.

Linda Linda was assigned to a self-contained first grade classroom in a small Southwestern Indiana city K-6 school with a student population of approximately 200. The 25 students in the class came from homes of varied socio-economic status and demonstrated a wide range of abilities.

Linda, whose area of concentration was language arts, was also a non-traditional student: older than her undergraduate peers and married with a son in kindergarten. She had commuted to campus (1½ hours each way) to attend classes. The slightly shorter commute (45-minutes each way) to her student teaching placement continued to challenge her time commitments and availability for interviews.

Data Collection

Because science content knowledge, pedagogical knowledge, and pedagogical content knowledge are such vast areas, aspects of each type of knowledge that were specifically addressed in the teacher education program at this institution were examined. Evidence was sought in the areas below:

Science Content Knowledge
- science as interdisciplinary in nature
- science as inquiry
- subjects' scientific conceptions

Pedagogical Knowledge
- teaching science using the learning cycle approach
- social interaction in learning science
- building instruction on children's prior conceptions
- problem solving and higher level learning
- allowing children to structure their own learning

Pedagogical Content Knowledge
- applying appropriate pedagogy in teaching a concept to a group of children
- adapting college instruction to pedagogy appropriate at the elementary/middle school level
- applying appropriate technology in teaching a given concept.

To establish triangulation in determining answers to the research questions, multiple data sources were considered (Glesne & Peshkin, 1992). These methods included observations, document collection, and self-evaluations. For the first phase of the investigation, data were collected during regular class sessions throughout the fall semester. Table 1 delineates the data collection timeline for the subject groups. On the first day of class, the capstone students completed a project-generated questionnaire, the Capstone Science Survey, assessing each of the three types of knowledge and an open-ended analysis of two elementary science lesson plans on dinosaurs. During the final class session, these students repeated the survey and analyzed two science lesson plans on electric circuits. At that time, the capstone group also completed two pedagogical surveys. Additional data were collected throughout the semester from those capstone students participating in the middle school practicum. They conducted interviews with some of the children in their practicum classrooms, planned and taught a variety of science lessons, completed personal lesson reflections after teaching, and assessed their own and their teaching partner's videotaped teaching performances. The control group of students with other areas of concentration completed only the three surveys and the second lesson plan analysis.

Data were collected throughout the spring semester during four separate school visitations to each student teacher by one of the researchers. Given the nature of the study, a comparative case study design was employed to determine answers to the research questions (Bogdan & Biklen, 1992). Each of the participating student teachers was asked to keep a personal journal throughout the semester as a reflective activity. During each on-site visit, interviews with the student teachers were conducted using a semi-structured protocol, audiotaped for later transcription and analysis. The student teachers were observed each time teaching a regular science lesson to their students. Two of the lessons were videotaped and the corresponding written lesson plans were collected for comparison to the lesson as presented. The student teachers also assessed their videotaped teaching performances. At the end of the semester, the nine student teachers completed four QUEST-developed instruments. Each of these instruments had been administered previously to all of the student teachers at least once during their teacher preparation program at the university. Therefore, some past data were available for comparison to consider the third research question. Table 2 provides a timeline of when the various data sources were administered during the teacher education program.

Qualitative Data

The qualitative data sources used in these investigations of the preservice teachers are described below.

Lesson Plan Analysis Two pairs of lesson plans devised for the students to compare and analyze as follows: (1) identify strengths and weaknesses of each plan, (2) describe how they would modify the plan if they were teaching the lesson, and (3) select appropriate assessment items from a given list. Dinosaurs and thermoregulation was the topic of the first set of plans. The topic of the second set was electric circuits.

Each lesson plan purposely contained both appropriate and inappropriate pedagogical procedures with correct and incorrect science content. For example, Teacher Brown's lessons began with a lecture and reading format with no hands-on activities for the children, followed by a cooperative group learning task (using the jigsaw approach) to research topics related to the main focus. Teacher Green's lesson plans were based on the learning cycle, beginning with an exploratory hands-on activity, continuing with a reading and/or discussion of the concepts, followed by an application activity. Intentional content errors such as statements about a) humans protecting themselves from dinosaurs, and b) electrons getting hot in the filament of a light bulb in an electric circuit were included in both plans in the pair of lessons.

Dinosaur Interviews A nine-question (three ordering, six free-response) survey of dinosaur concepts. The practicum students asked the same questions of selected children in their middle school classes.

On-site Observation Descriptions of the preservice teacher in action in the classroom, focusing on lesson presentation and management, interaction with students, classroom environment, etc.

Semi-structured Interview A set of questions presented verbally to the student teachers covering their science content knowledge, pedagogical knowledge, and pedagogical content knowledge, allowing for some departure to clarify a respondent's comments.

Unit/Science Lesson Plans Participant-generated lesson plan or a series of science lesson plans on a self-selected topic, taught in the practicum setting.

Lesson Reflections A series of 8 questions intended to guide the students' reflections on their lesson plans and teaching performances.

Videotaped Lesson Videotaped recording of the preservice teacher's presentation of one of their science lesson plans.

Video Self-assessment Semi-structured questions to guide the preservice teacher's reflection of their lesson and its presentation after viewing the videotape. (Each practicum student also assessed their teaching partner's videotaped lesson and performance.)

Student Teaching Journal Reflective writings throughout the student teaching experience.

Final Examination Free-response items selected by the capstone students from a given list, including classroom situations and lesson planning.

Quantitative Data

The instruments providing quantitative data are described below. The preservice teachers' responses to the surveys provided qualitative information in addition to that culled from the sources listed in the section above.

Capstone Science Survey A Likert Scale questionnaire containing 24 items that assess each of the three types of knowledge (science content = 7, pedagogy = 10, and pedagogical content = 7); statements are in a random order on the instrument, with the type of knowledge identifiers omitted.

Attitude Toward Self as Science Teacher A Likert Scale questionnaire consisting of 20 items that indicate the respondent's self-reflection as a science teacher.

Science Content Test A multiple-choice test of 10 items each in the areas of life science, earth science, physical science, and the nature of scientific inquiry.

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Teaching Survey A 20-item Likert Scale questionnaire that measures a constructivist philosophy of teaching versus a more traditional perspective.

Summary of Results and Discussion

Capstone Group versus Control Group

Science Content Knowledge

The aspects of science content knowledge examined in this study were: 1) the interdisciplinary nature of science, 2) science as inquiry, and 3) the subjects' scientific conceptions. A specific question for each of these areas was developed to guide the analysis of data.

Do students perceive that science has no boundaries, that science is integrated and is interdisciplinary in nature? The preservice teachers in the capstone and control groups are limited in their understanding of the interdisciplinary nature of science. Their perception of integration is that of science with other subjects in the school curriculum. This may be due to the elementary education majors overall preparation as a content generalist, and the current push to correlate subjects at the elementary and middle school levels.

Do students perceive that science consists of inquiry using experimentation, the collection of data leading to generalization, rather than only memorizing facts? The results for both groups were similar. There was definite support for science as "doing." However, there was some indication that these preservice teachers cannot totally discount science as a collection of facts. The previous year's capstone group also viewed science as more factual at the end of the semester. At the time, those findings were attributed to the emphasis on astronomy content in the first capstone course. The geology instructors had diligently worked to de-emphasize content with the second capstone class. Perhaps the students cannot overcome the poor modeling they've witnessed throughout their schooling.

Do students possess scientific concepts rather than naive concepts about the discipline(s)? The results for both of the groups on the Capstone Science Survey and the second lesson plan analysis were remarkably similar. Because the control group's data were more limited than the capstone group's, it cannot be determined whether or not familiarity with the content affected these findings. However, the topic of the second lesson plan analysis should have been familiar to all of these preservice teachers because electricity was emphasized in the required physics course.

Pedagogical Knowledge

The aspects of pedagogical knowledge examined in this study were: 1) the learning cycle, 2) social interaction, 3) children's prior conceptions, 4) higher level learning, and 5) children structuring their own learning. The results are presented with the specific question used to guide the

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analysis.

Do students value teaching science using the learning cycle approach? The data for this pedagogical aspect was limited by the preservice students' lack of identifying the learning cycle approach to teaching science to children. While neither group showed a true commitment for this teaching strategy, a few of the capstone students were able to exhibit some understanding of it in their practicum lessons. Because the learning cycle was emphasized in the elementary science methods course and the capstone course laboratory, these findings were rather disheartening.

Do students value the role of social interaction (cooperative learning) in learning science? Students in both groups agreed that social interaction is important for children to learn science. However, their reasons for this were somewhat unclear. Perhaps the groups were so agreeable on the survey because the statements "sounded good" to them. These preservice teachers are continually grouped in education classes to complete activities and assignments. Other methods courses emphasize group teaching practices as well, perhaps not modeling the techniques adequately. Ultimately, their commitment to cooperative learning is questionable.

Do students see the value of building instruction on children's prior conceptions? With such high percentages (over 90%) of support on the Capstone Science Survey for prior knowledge, it was expected that this pedagogical topic would be mentioned by the preservice teachers in the lesson plan analyses or given a high priority in teaching lessons. However, eliciting prior knowledge was not exhibited by either group of preservice teachers. The findings are particularly disturbing because the preservice teachers are given opportunities to work through their own misconceptions in science content and methods courses.

Do students value the role of problem solving and higher level learning versus rote learning? The capstone and control groups again had similar results. They showed some support for problem solving and higher order learning on the survey and in their lesson plan analyses. In addition, many of the practicum students incorporated these pedagogical aspects into their lessons for children.

Do students value allowing children to structure their own learning? This may be the area of greatest difference between the capstone and control groups. There was little evidence of support for student choice among the capstone students, whereas some of the control students' strongest statements concerned allowing children to structure their own learning. Perhaps the capstone students who were not participating in the practicum experience were influenced in this area by those who were teaching middle school students. Presenting teacher-directed, or highly-structured lessons is a classroom management technique for maintaining control over students.

Pedagogical Content Knowledge

The aspects of pedagogical content knowledge examined in this study were 1) applying appropriate pedagogy, 2) adapting college instruction to the appropriate level, and 3) applying appropriate technology. Evidence for the specific question developed for each aspect is discussed below.

Do students apply the appropriate pedagogy in teaching a concept to a group of children? The QUEST Teaching Survey results were overwhelmingly similar for the capstone and control groups (see Table 4). The pattern of distributions across the **strongly agree - strongly disagree** categories was strikingly obvious. On paper, all of these preservice teachers support a constructivist philosophy of teaching. The question remains whether or not these prospective educators can transfer their ideas into practice.

The responses to the survey statements may indicate the preservice teachers' uncertainty of the appropriateness of specific activities for science concepts which are unfamiliar to them or for which they need some review. Because these elementary education majors were unaware of the science content contained in the lesson plans for analysis and the Capstone Science Survey, they were drawing from their mental structures that may never have processed the information needed to consider the appropriateness of the particular activities.

Can students adapt what is taught to them at the college level to pedagogy appropriate at the elementary/middle school level? The results for the capstone and control groups were similarly low. This may be due to the students' lack of content knowledge of the science concepts in the lesson plan analyses and the survey, at the time of their administration. Perhaps with preparation/study time, as is more representative of the inservice experience, these preservice teachers would have suggested and used more pedagogically appropriate ideas.

Do students apply the appropriate technology in teaching a given concept? Again, the results for the capstone and control groups were disappointing. Obviously, these preservice teachers do not value technology in the science classroom. Similar results were seen in the pilot study with the first capstone group where few of the practicum students incorporated any technology in their self-generated lessons. This is especially disheartening due to the time that all of these students spent in elementary science education courses working with computers and various peripherals, videodiscs, and linkages to NASA and the US Geological Survey.

Attitudes Toward Teaching

During the final data collection periods, the capstone group and the control group completed the project-generated survey called Attitude Towards Self as Science Teacher. The pattern of distribution across categories was similar between groups (see Table 4). Overall results were quite positive. The preservice teachers in both groups expressed their confidence in preparation to teach science and a sense of looking forward to teaching science to children. There was a rather noticeable difference between the groups on only one statement: "Science is my main interest in the field of education." Although there was not unanimous agreement, even among the science concentration students, the majority of the control group students did disagree. This, however, was not an unexpected outcome.

QUEST Student Teachers versus NonQUEST Student Teachers

Science Content Knowledge

Integrating the sciences was not observed in the student teachers' science teaching. From the interviews, it appeared that all of these preservice teachers perceived that the interdisciplinary nature of science was incorporating other content areas with science, rather than integrating the sciences. This view may have resulted from the presentation of integrated curricula formats in methods courses for several different subject areas.

In interviews and on the surveys, all of the student teachers communicated that an inquiry approach to teaching science was important for children. However, two of the nonQUEST students were unable to translate that belief into practice. Linda emphasized facts, and Elaine used discussion rather than activities.

Although the Capstone Science Survey and the Science Content Test revealed that all of these preservice teachers have some weakness in particular content areas, the student teachers expect to overcome those difficulties by preparing well before teaching troublesome or unfamiliar concepts. All, but Elaine (nonQUEST), expressed confidence in their ability to teach science to elementary children.

Pedagogical Knowledge

The pedagogical practices utilized by these nine student teachers varied from individual to individual. School expectations, classroom management, and time constraints seemed to influence general classroom procedures.

The learning cycle was used extensively by individuals in each subject group, but the others neglected the culminating application phase. This was especially disheartening due to the emphasis on the learning cycle in all sections of the elementary science methods and its complementary field experience. The approach used in the methods course was quite similar to that espoused by Barman (1992).

Those aspects of pedagogy somewhat neglected by most of the student teachers were cooperative group learning, problem solving and higher level learning, and children's choice. Although each of them demonstrated their value of social interaction in science learning by pairing or grouping students, only Beth (QUEST) used true cooperative learning in her science classes. Michelle (QUEST) consistently expected her students to answer thoughtful, higher level questions, contrary to the others' propensity to ask recall or review questions. Only Carla (QUEST) provided opportunities for children to structure their own learning in science.

Eliciting prior knowledge was the one area showing a real difference between the QUEST groups and the nonQUEST student teachers. The QUEST groups showed little regard for the children's conceptions in their observed lessons throughout the semester, even though this area was greatly emphasized in the methods and capstone courses. However, all of the nonQUEST student teachers were noted as increasing their time listening to the children discuss past experiences and their understanding of the science concepts in a lesson.

Pedagogical Content Knowledge

All of these student teachers seemed to be continually developing their understanding of appropriate pedagogical methods, and there were no observable differences between QUEST and nonQUEST students in this regard. Individual differences among these preservice teachers were more pronounced in considering aspects of pedagogical content knowledge. As the semester progressed, those who weren't experiencing classroom management difficulties seemed to nurture their burgeoning confidence in science content and pedagogical knowledge, allowing them to make more appropriate decisions in the teaching of science to elementary children. Those stifled by other constraints, personal or professional, communicated in interviews or surveys what they should be doing as science teachers, but they experienced problems in putting into practice their ideals.

What is most evident in this section is that the lack of technology in the schools definitely hinders how science content is presented. Although all nine of the student teachers had opportunities at the university to observe and utilize various pieces of high technology, few schools in this area possess the equipment or adequately use what is available to them.

Conclusions and Implications

From the attitude survey alone, it might be concluded that the preservice elementary teachers who participated in this study hold positive attitudes that may result in good elementary science teaching in their classrooms. From the Teaching Survey results, the conclusion may be that these preservice teachers support, and will subsequently practice, a constructivist teaching philosophy. However, data collected from the other sources used in this investigation do not support those judgements. The overall results for the capstone group and the control group for those aspects of science content knowledge, pedagogical knowledge, and pedagogical content knowledge examined in this study were much lower than anticipated.

The overall findings for the student teachers were also somewhat disappointing. The students held their own interpretation of the interdisciplinary nature of science, espoused inquiry without always practicing it, and admitted that they did not know or understand all of the content they were expected to teach at the elementary level. Perhaps the most distressing observation was that few of the student teachers regularly incorporated in their science lessons teaching strategies such as the learning cycle, cooperative learning, and problem solving that had been emphasized in methods courses. The level of pedagogical content knowledge demonstrated by the student teachers seemed directly related to the individual's ability to cope with classroom management concerns.

Regarding the results for science content knowledge, it is understandable that these undergraduate students have little perception of the interdisciplinary nature of science. Science content courses at the high school and college levels are continually departmentalized into the science disciplines. Each of the sciences at Indiana University have specific buildings for their classrooms and laboratories. It should not be expected that one integrated science content class, the capstone course, would change deeply-rooted beliefs. That these students perceive science as

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a collection of facts may be explained by the emphasis on content they have experienced throughout their years of schooling. Although the results showed that these students had difficulty with the science content within some of the study instruments, the practicum participants' conceptual understanding was found to be greater for those science content areas they were teaching. It is unfair, indeed, to expect the elementary education major to remember every science concept he or she has studied.

Concerning pedagogical knowledge, one important conclusion that can be determined from this investigation is that paper-and-pencil assessments are not sufficient to predict what will actually take place in the classroom. The response category circled or the comments written in analysis of lessons were not supported by the pedagogical knowledge expressed in teaching situations. Observations of preservice teachers working with children is necessary. "Observation of actual practice reveals how the different things that a teacher knows and believes come together in making decisions and pedagogical moves" (Kennedy, Ball, & McDiarmid, 1993, p. 99). On written instruments these preservice teachers supported the learning cycle, cooperative learning, eliciting children's prior knowledge, problem solving, and student choice, however, they seemingly ignored these aspects of pedagogy in real-life teaching situations.

Moving from the theoretical orientation of the methods courses to the practical application expected in the elementary classroom presents challenges to all preservice teachers. Hill, Lee, and Lofton (1991) suggest that student teachers often have trouble adapting what they've learned in methods courses for use in the actual classroom and "planning for real students instead of for a profession" (p. 29). Although there was variety between individuals, among groups the student teachers demonstrated similar pedagogical knowledge. This may be explained by the repeated consideration of these aspects of pedagogy in other teacher education courses, common to all of the student teachers.

The practicum students demonstrated obvious problems translating theory into practice. Spector (1989) noted that beginning science teachers

> frequently emulate the ways of their college science professors, relying on a lecture/demonstration approach ... and generally ignore the individual student's learning needs. Some of the conflicts ... stem from the perception that there is an unbridgeable chasm between what they learned in the university and what is feasible in the school. (p. 63)

To bridge the chasm between methods classes and practice, opportunities for videotaping science lessons, self-assessment, and reflection were assignments for the middle school practicum and the student teaching experience. As Struyk (1991) asserts, "Many teachers are willing to make necessary changes in their teaching provided they have access to data indicating where they should begin. Through self-evaluation, teachers can observe and analyze their teaching and then make decisions based on the analysis" (p. 18). Assessing the practicum partner's videotaped lesson was derived from a study of elementary student teachers suggesting "that an important element of effective tasks may be giving novices access to one another's classroom performances, perhaps having them critique one another's lessons. . ." (Kagan & Tippins, 1990, p. 352). However, the students in this study gave rather superficial critiques of themselves and their peers. Other researchers have found this same lack of depth with

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elementary and secondary education students (Mostert & Nuttycombe, 1991).

As the results for pedagogical content knowledge showed, the preservice teachers in this study appropriately applied and adapted pedagogy for science concepts with which they were directly involved, usually through planning and teaching lessons. According to their responses on the attitude survey, most of them believed that they were prepared to teach science to elementary children. While none of the nine student teachers demonstrated a truly adequate pedagogical content knowledge, the six QUEST students consistently expressed and displayed more confidence in their abilities to teach science to children. Perhaps it is more important to science education that beginning elementary teachers leave the teacher preparation program with a basic confidence, and willingness, to teach science. Their expertise in particular areas can then be developed.

It was apparent that the idealism of the new educator, fresh from the university setting, sometimes twisted into the unexpected reality of the elementary classroom. From his research with preservice science and math teachers, Latz (1992) "suggests that there is a strong link between a teacher's instructional approach and classroom management" (p. 3). He asserts that beginning teachers are prescriptive and try to deal with individual problems, as did the student teachers in this study. It is only through experience that their "methods became more preventative" (p.3). Many of these student teachers exhibited the same characteristics Spector (1989) identified as typical of beginning teachers:

> Teachers in Stage I focus on their own survival .... They do not want to make decisions and prefer to be told one best way to teach ... avoiding laboratory activities whenever possible out of fear that they will lose control of students. (p. 62)

The nonQUEST student teacher Elaine exemplified this description with her comments on teaching a "challenging" group of students.

Although none of the nine student teachers had expressed a strongly negative attitude toward teaching science before the spring semester began, their comments at the study's conclusion were strikingly positive and enthusiastic. West, Thomson, Watson, and Parke (1993) found that ". . . preservice elementary teachers' attitudes toward science and science teaching were significantly improved during student teaching. Anxiety levels of the preservice teachers were also reduced significantly during the student teaching experience" (p. 9). During the interviews at the end of the student teaching experience investigated in this study, only Elaine (nonQUEST) expressed some remaining uneasiness about teaching science to children.

From the case study of Marie, a science enthusiast student teacher, Abell and Roth (1992) assert that "Limited content and pedagogical content knowledge may be the biggest constraint for novice teachers in elementary science, especially those who do not begin as science enthusiasts. Unfortunately it is not a constraint that is ameliorated by experience or increased confidence alone" (p. 592). The same conclusion cannot be drawn from this investigation of preservice elementary teachers. Several of these student teachers repeatedly attributed their discrepant actions to constraints of time, discipline problems, or the school environment. They expressed confidence that, over time, they would develop pedagogical skills enabling them to teach science to children more effectively.

Perhaps Lederman and Gess-Newsome (1992) ask a most important question in "What is pedagogical content knowledge?" (p. 19). Are inexperienced educators, such as fledgling student teachers, capable of demonstrating other than a minimal level of pedagogical content knowledge? How can a beginning teacher be expected to possess a repertoire of pedagogical skills from which they can select the most appropriate way of presenting particular science concepts to children? Expertise develops over time. Educators must respect the old adage: Experience is the best teacher.

Ultimately, the impact on future students of these preservice teachers must be considered. These novice educators teach as they were taught. Curricular developments such as conceptual change learning techniques won't be used with another generation of students unless new teachers experience conceptual change learning for themselves on a continuing basis. As Rhoton (1994) states, "Substantial improvements in K-12 science will require change in the way undergraduate science courses are taught" (p. 261). Even though conceptual change was a major component in several of the newly developed courses included in the QUEST project, it must become the norm, not only for courses at the college level, but for all science courses throughout a student's education.

References

Abell, S.K. (1990). A case for the elementary science specialist. School Science and Mathematics, 90, 291-301.

Abell, S.K., & Roth, M. (1992). Constraints to teaching elementary science: A case study of a science enthusiast student teacher. Science Education, 76, 581-595.

Barman, C.R. (1992). An evaluation of the use of a technique designed to assist prospective elementary teachers to use the learning cycle with science textbooks. School Science and Mathematics, 92, 59-63.

Bogdan, R.C., & Biklen, S.K. (1992). Qualitative research for education: An introduction to theory and methods (2nd ed.). Boston: Allyn and Bacon.

Borko H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. American Educational Research Journal, 26, 473-498.

Clermont, C.P., Borko, H., & Krajcik, J.S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. Journal of Research in Science Teaching, 31, 419-441.

Doyle, W. (1990). Classroom knowledge as a foundation for teaching. Teachers College Record, 91, 347-360.

Ginns, I.S. & Watters, J.J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. Journal of Research in Science Teaching, 32, 205-222.

Glesne, C., & Peshkin, A. (1992). Becoming qualitative researchers: An introduction. White Plains, NY: Longman.

Grossman, P.L., Wilson, S.M., & Shulman, L.S. (1989). Teachers of substance: Subject matter knowledge for teaching. In M.C. Reynolds (Ed.), Knowledge base for the beginning teacher (pp. 23-36). Oxford: Pergamon Press.

Hill, F.H., Lee, A.M., & Lofton, G.G. (1991). Assessing the relationship between reflective practice, content knowledge, and teaching effectiveness of student teachers. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 338 565)

Kagan, D.M., & Tippins, D.J. (1990). Helping student teachers attend to student cues. The Elementary School Journal, 91, pp.343-356.

Kennedy, M.M., Ball, D.L., & McDiarmid, G.W. (1993). A study package for examining and tracking changes in teachers' knowledge (Report No. NCRTL-TS-93-1). East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED 359 170)

Latz, M. (1992). Preservice teachers' perceptions and concerns about classroom management and discipline: A qualitative investigation. Journal of Science Teacher Education, 3, 1-4.

Lederman, N.G., & Latz, M. (1993). Emergence and interactions of knowledge structures in the preservice teacher. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA.

Lederman, N.G. & Gess-Newsome, J. (1992). Do subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge constitute the ideal gas law of science teaching? Journal of Science Teacher Education, 3, 16-20.

Magnusson, S., & Krajcik, J. (1993). Teacher knowledge and representation of content in instruction about heat energy and temperature. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA.

McDiarmid, G.W., Ball, D.L., & Anderson, C.W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In M.C. Reynolds (Ed.), Knowledge base for the beginning teacher (pp. 193-205). Oxford: Pergamon Press.

Mostert, M.P., & Nuttycombe, D.G. (1991). Prospective teachers' perceptions of a teaching episode (Technical Report). Charlottesville, VA: University of Virginia, Curry School of Education, Commonwealth Center for the Education of Teachers. (ERIC Document Reproduction Service No. ED 350 293)

Rhoton, J. (1994). The role of higher education in precollege science education reform. Journal of College Science Teaching, 23, 260-262.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Shulman, L.S. (1987). Knowledge of teaching: Foundations of the new reform. Harvard Educational Review, 57, 1-22.

Smith, D.C. & Neale, D.C. (1989). The construction of subject matter knowledge in primary science teaching. Teaching & Teacher Education, 5, 1-20.

Spector, B.S. (1989). What research says . . . about stages of professional development. Science and Children, 27, (1), 62-65.

Stofflett, R.T. (1994). The accommodation of science pedagogical knowledge: The application of conceptual change constructs to teacher education. Journal of Research in Science Teaching, 31, 787-810.

Stofflett, R.T., & Stoddard, T. (1994). The ability to understand and use conceptual change pedagogy as a function of prior content learning experience. Journal of Research in Science Teaching, 31, 31-51.

Struyk, L.R. (1991). Self-evaluation procedures for teachers. Paper presented at the summer conference of the Association of Teacher Educators, Minot, ND. (ERIC Document Reproduction Service No. ED 336 361)

Tamir, P. (1991). Professional and personal knowledge of teachers and teacher educators. Teachers & Teacher Education, 7, 263-268.

Tippins, D.J., Kagan, D.M., & Jackson, D.F. (1993). How teachers translate learning theory into instruction: A study of group problem solving by prospective secondary science teachers. In P.A. Rubba, L.M. Campbell, & T.M. Dana (Eds.), Excellence in educating teachers of science (pp. 55-68). Columbus, OH: The Ohio State University, Clearinghouse for Science Mathematics and Environmental Education.

West, S.L., Thomson, W.S., Watson, S.B., & Parke, H. (1993). The effect of the student teaching experience upon preservice elementary teachers' attitudes and anxiety involving science and science teaching. Greenville, NC: East Carolina University, School of Education. (ERIC Document Reproduction Service No. ED 365 542)

Wilson, S.M., Shulman, L.S., & Richert, A.E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teachers' thinking (pp.104-124). London: Cassell.

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Table 1 **Preservice Teachers Data Collection during Fall Semester**

Data Source	Capstone Group with MS Practicum (n = 12)	Capstone Group Elementary Only (n = 12)	Control Group (n = 25)
Capstone Science Survey			
Pre	Week 1	Week 1	
Post	Week 15	Week 15	Week 14
Lesson Plan Analysis			
#1	Week 1	Week 1	
#2	Week 15	Week 15	Week 14
Dinosaur Interview			
Capstones	Week 1	Week 1	
Practicum students	Week 3		
Unit Lesson Plans			
#1	Week 7		
#2	Week 11		
Lesson Reflections			
#1	Week 12		
#2	Week 15		
Videotaped Teaching			
Lesson	Weeks 11-14		
Self-assessment	Weeks 12-15		
Partner Assessment	Weeks 12-15		
Attitude Toward Self as Science Teacher	Week 15	Week 15	Week 14
Teaching Survey	Week 15	Week 15	Week 14
Final Examination	Week 15	Week 15	

Note. The subjects in the capstone group were separated to illustrate more clearly the sources of data for each group.

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Table 2 **Data Collection Timeline for Each Course Semester**

Data Source	Scientific Inquiry Course[a]	Elementary Science Methods Course[a]	Capstone Course[b]	Student Teaching[c]
Observation				throughout
Interview				throughout
Lesson Plans				middle and end
Videotaped Teaching and Self-assessment				middle and end
Student Teaching Journal				throughout
Capstone Science Survey			beginning[d] and end	end
Attitude Toward Self as Science Teacher	beginning	end	end	end
Science Content Test	beginning	middle		end
Teaching Survey		beginning and end	end	end

Note. [a] Data were collected from all elementary education majors in this course.
[b] Data were collected from science concentration students and the control group of students with other areas of concentration.
[c] Data were collected from the nine student teachers only.
[d] Data were collected from the science concentration students only at this time.

Table 3

Percentages of Responses to Teaching Survey Statements

Statement	Strongly Agree (Cap[a])	Strongly Agree (Con[b])	Agree (Cap)	Agree (Con)	No Opinion (Cap)	No Opinion (Con)	Disagree (Cap)	Disagree (Con)	Strongly Disagree (Cap)	Strongly Disagree (Con)
1. When children are exploring a new concept, the teacher should act primarily as a consultant for the students.	8.7	20.0	87.0	68.0	0.0	0.0	0.0	12.0	4.3	0.0
2. Teachers should begin the study of any concept with explanations and definitions.	0.0	4.0	4.3	16.0	13.0	12.0	65.2	56.0	17.4	12.0
3. Students should check their understanding of a given topic with their peers.	13.0	12.0	73.9	56.0	13.0	8.0	0.0	4.0	0.0	0.0
4. When solving a problem, students should be seeking one acceptable solution.	4.3	0.0	4.3	4.0	0.0	4.0	73.9	44.0	17.4	48.0
5. Teachers should encourage students to work together to solve problems.	34.8	64.0	60.9	36.0	0.0	0.0	4.3	0.0	0.0	0.0
6. Teachers should lead students step-by-step to the correct solutions to problems.	0.0	0.0	0.0	4.0	21.7	16.0	52.2	28.0	26.1	52.0
7. Students should be told when they are incorrect if they have not come up with the correct solution to a problem.	4.3	4.0	26.1	20.0	21.7	20.0	30.4	40.0	17.4	16.0
8. Teachers should encourage students to explain concepts and definitions in their own words.	21.7	76.0	69.6	24.0	4.3	0.0	4.3	0.0	0.0	0.0
9. A primary role of the teacher is relating facts to children.	0.0	0.0	13.0	20.0	17.4	8.0	52.2	44.0	17.4	28.0
10. Teachers should encourage students to use previous experiences as a basis for explaining new concepts.	34.8	56.0	60.9	44.0	4.3	0.0	0.0	0.0	0.0	0.0
11. When solving problems, students should work quietly at their desks without interacting with other students.	0.0	0.0	0.0	0.0	0.0	0.0	56.5	24.0	43.5	76.0
12. Students should continue working once they have come up with a solution to a particular problem.	4.3	24.0	78.3	60.0	8.7	12.0	8.7	4.0	0.0	0.0
13. The students should listen critically to explanations and solutions offered by other students.	34.8	48.0	56.5	52.0	8.7	0.0	0.0	0.0	0.0	0.0
14. Teachers should not expect students to justify their explanations and answers.	0.0	0.0	4.3	0.0	4.3	0.0	69.6	32.0	21.7	68.0
15. Students should accept explanations that are given from teachers without questioning.	0.0	0.0	13.0	0.0	4.3	0.0	56.5	32.0	26.1	68.0
16. Students should explain possible solutions to problems to other students.	8.7	52.0	82.6	48.0	4.3	0.0	0.0	0.0	4.3	0.0
17. Students should not accept explanations from each other that are given without justification.	0.0	12.0	47.8	52.0	21.7	16.0	26.1	16.0	4.3	4.0
18. Teachers should provide definitive answers to questions that are raised in the classroom.	0.0	0.0	8.0	30.4	16.0	34.8	24.0	34.8	40.0	12.0
19. After learning about a given topic, students should use only the vocabulary the teacher has provided in further discussions about that topic.	4.3	0.0	0.0	0.0	8.7	8.0	69.6	52.0	17.4	40.0
20. Teachers should ask students to provide justification for their answers.	4.3	60.0	73.9	36.0	13.0	4.0	0.0	0.0	8.7	0.0

Note. [a] Capstone group, n = 21. [b] Control group, n = 25.

Table 4

Percentages of Responses on Attitude Towards Self as Science Teacher

Statement	Strongly Agree (Cap[a])	Strongly Agree (Con[b])	Agree (Cap)	Agree (Con)	No Opinion (Cap)	No Opinion (Con)	Disagree (Cap)	Disagree (Con)	Strongly Disagree (Cap)	Strongly Disagree (Con)
1. The content knowledge I possess is adequate to teach elementary science.	9.5	4.0	80.9	56.0	4.7	20.0	0.0	16.0	4.7	4.0
2. I feel indifferent towards the emphasis put on the teaching of science in elementary education.	4.7	4.0	19.0	0.0	19.0	28.0	42.8	44.0	14.3	24.0
3. I have positive feelings about my preparation for teaching science.	19.0	8.0	711.4	64.0	4.7	8.0	4.7	12.0	0.0	8.0
4. Teaching science will be an enjoyable experience.	47.6	28.0	52.4	56.0	0.0	8.0	0.0	8.0	0.0	0.0
5. It is difficult to motivate children to want to learn about science.	0.0	0.0	9.5	4.0	0.0	4.0	66.7	56.0	23.8	36.0
6. I feel I have the skills necessary to inspire children to want to learn about science.	14.3	8.0	85.7	72.0	0.0	12.0	0.0	8.0	0.0	0.0
7. I feel prepared to meet the challenge of teaching elementary science.	9.5	8.0	81.0	52.0	4.7	24.0	0.0	12.0	4.7	4.0
8. I am not excited by the prospect of teaching elementary science.	0.0	8.0	4.7	4.0	0.0	4.0	47.6	60.0	47.6	24.0
9. Elementary teachers should possess a broad range of knowledge in various areas of science.	33.3	48.0	66.7	40.0	8.0	4.0	0.0	0.0	0.0	0.0
10. Science is my main interest in the field of education.	23.8	0.0	47.6	8.0	14.3	12.0	9.5	56.0	4.7	24.0
11. My background has not prepared me to teach elementary science.	0.0	0.0	0.0	8.0	9.5	16.0	57.1	60.0	33.3	16.0
12. I believe I will convey an enthusiastic attitude towards science to children.	33.3	36.0	61.9	60.0	0.0	4.0	4.7	0.0	0.0	0.0
13. I feel uneasy about the prospect of teaching science.	0.0	8.0	4.7	28.0	0.0	12.0	57.1	40.0	38.1	12.0
14. I feel I am unqualified to teach elementary science.	4.7	4.0	9.5	12.0	0.0	4.0	57.1	56.0	28.6	24.0
15. As a student, I feel I am being adequately prepared to teach science.	0.0	12.0	71.4	44.0	19.0	20.0	9.5	16.0	0.0	8.0
16. I would prefer not to teach science.	0.0	4.0	4.7	4.0	4.7	20.0	28.6	44.0	61.9	28.0
17. I feel proficient in the areas needed to teach elementary science.	9.5	0.0	85.7	76.0	0.0	16.0	4.7	4.0	0.0	4.0
18. I would be uncomfortable teaching elementary science.	4.7	4.0	4.7	8.0	4.7	0.0	23.8	60.0	61.9	28.0
19. I do not believe I can relay pertinent science material to children.	0.0	0.0	0.0	4.0	4.7	0.0	61.9	72.0	33.3	24.0
20. I look forward to the likelihood of teaching science in the classroom.	52.4	20.0	42.8	60.0	0.0	12.0	0.0	4.0	4.7	4.0

Note. [a] Capstone group, n = 21. [b] Control group, n = 25.

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