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ABSTRACT

This study documents and interprets the efforts made by one elementary science methods professor to make connections between mathematics and science in an elementary science methods course. This is an action research study using an N of one (a case study) from the theoretical stance of symbolic interaction. Participants in this study include the course professor, a co-researcher, and the 30 teacher candidates in the course. Special focus is on six teacher candidates participating in a National Science Foundation funded undergraduate teacher preparation program designed to produce specialist mathematics and science upper elementary/middle level teachers and on three elementary education majors with concentrations in mathematics or science. Discussion focuses on the researchers' reflections as prompted by a comparison of the performance of the special teacher candidates' and the other teacher candidate participants. A key implication from this study is the assertion that while all participants benefited from the teaching innovation to blend mathematics and science in the methods course, the teacher candidates participating in the specialist program were particularly receptive to and accomplished in making connections between mathematics and science. The authors believe that they benefited preferentially due to their prior experience in content specialist classes in which the professors emphasized connections between the two disciplines. However, the authors also advise caution in implementing this innovation in all contexts. A major finding is that teacher candidates are inclined to construct visions of the role of mathematics and science when making connections, which specialists in the disciplines might find problematic. (Author/DDR)

An Action Research Perspective Of Making Connections Between Science And Mathematics In A Science Methods Course

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Abstract

This study documents and interprets the efforts made by one elementary science methods professor to make connections between mathematics and science in an elementary science methods course. This is an action research study using an N of one (a case study) from the theoretical stance of symbolic interaction. Participants in this study include the course professor and a coresearcher and the thirty teacher candidates in the course. Special focus is on six teacher candidates participating in a National Science Foundation funded undergraduate teacher preparation program designed to produce specialist mathematics and science upper elementary/middle level teachers and on three elementary education majors with concentrations in mathematics or science. Discussion focuses on the researchers' reflections as prompted by a comparison of the performance of the special teacher candidates' and the other teacher candidate participants. A key implication from this study is the assertion that while all participants benefited from the teaching innovation to blend mathematics and science in the methods course, the teacher candidates participating in the specialist program were particularly receptive to and accomplished in making connections between mathematics and science. We believe that they benefited preferentially due to their prior experience in content specialist classes in which the professors emphasized connections between the two disciplines. However, we also advise caution in implementing this innovation in all contexts. We learned that teacher candidates are inclined to construct visions of the role of mathematics and science when making connections which specialists in the disciplines might find problematic.

An Action Research Perspective Of Making Connections Between Science And Mathematics In A Science Methods Course

There is considerable interest currently in preparing science teachers to make connections with other disciplines, particularly mathematics. However, there are a dearth of empirical studies that systematically study the implementation of this teaching innovation. This study documents and interprets the extensive efforts made by one elementary science methods professor to make curriucular connections between mathematics and science throughout a special section of an elementary science methods course at a major research university. The elementary science methods course included six teacher candidates participating in a special National Science Foundation funded undergraduate teacher preparation program designed to produce specialist mathematics and science upper elementary/middle level teachers, the Maryland Collaborative for Teacher Preparation (MCTP).

Purpose and Relevant Background

In this study, the construction of a vision by teacher candidates for the role of mathematics and science when they are connected curricularly was of primary interest. The participants are the professor, his coresearcher, and thirty teacher candidates who were enrolled in the elementary science methods course. Special focus is on six teacher candidates participating in a National Science Foundation funded undergraduate teacher preparation program designed to produce specialist mathematics and science upper elementary/middle level teachers and on three elementary education majors with concentrations in mathematics or science. Insights are generated by the researchers as prompted by a comparison of the performance of the special teacher candidates' and the other teacher candidate participants. The six MCTP teacher candidates brought to the senior level methods block extensive prior experience of being in reform-based classes. They had been taught by mathematics and science professors who were participants in the MCTP and structured their courses in a reform-based manner.

The context of this teaching innovation is a National Science Foundation funded undergraduate teacher preparation program, the Maryland Collaborative for Teacher Preparation [MCTP]. The MCTP is a statewide undergraduate program. A fundamental assumption of the MCTP is that changes in pre-secondary level mathematics and science educational practices require reform within the undergraduate mathematics and science subject matter and education classes teacher candidates take throughout their teacher preparation programs (NSF, 1993). While teacher candidates selected to participate in the MCTP program in many ways are representative of typical teacher candidates in elementary teacher preparation programs, they are distinctive by expressing an interest in teaching mathematics and/or science. The goal of the MCTP is to promote the development of professional teachers who are confident teaching mathematics and science using technology, who can make connections between and among the disciplines, and who can provide an exciting and challenging learning environment for students of diverse backgrounds (University of Maryland System, 1993). This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities (National Council of Teachers of Mathematics [NCTM], 1989, 1991; American Association for the Advancement of Science [AAA] 1989, 1993; National Research Council [NRC] of the National Academy of Sciences, 1989, 1996). Figure 1 contains a program overview of the MCTP.

In practice, the MCTP undergraduate classes are taught by faculty in mathematics, science, and education who make efforts to focus on "developing understanding of a few central concepts and to make connections among the sciences and between mathematics and science" (MCTP, 1996, p. 2). Faculty also strive to infuse technology into their teaching practices and to employ instructional and assessment strategies generally deemed compatible with the constructivist perspective (i.e., address conceptual change, promote reflection on changes in thinking, and stress logic and fundamental principles as opposed to memorization of unrelated facts) (Cobb, 1988; Driver, 1989; Tobin, Tippins, & Gallard, 1994; von Glasersfeld, 1987, 1989; Wheatley, 1991). A primary referent for MCTP faculty on teaching and learning from a constructivist perspective is *The Case for Constructivist Classrooms* (Brooks & Brooks, 1993). Faculty lecture is diminished and student-based problem-solving is emphasized in cross-disciplinary mathematical and scientific applications.

Research Questions

As a result of the teacher candidates' participation in the MCTP reform-based science and mathematics courses, the following research questions were investigated:

1. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the science content knowledge they bring to their science methods course?

2. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions they bring to their science methods course concerning:

a. preparedness to teach science content to elementary students?

b. an appropriate science learning environment for elementary students?

c. the rationale for and intent to make connections between science and mathematics in elementary teaching?

d. the role of science methods in their teacher preparation program?

3. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions upon completion of the science methods course concerning:

a. an appropriate science learning environment for elementary students?

b. the extent to which their science methods professor modeled good teaching of science?

c. the extent to which they observed their science methods professor making connections to mathematics in his teaching?

d. the rationale for and intent to make connections between science and mathematics in elementary teaching?

4. From this teaching innovation experience, what did the science methods professor and his coresearcher learn that relates to the teaching of making connections between mathematics and science in an elementary science methods course?

Research Methodological Approaches

This is an action research study (Collins, 1995; Gore & Zeicher, 1991; Hollingsworth, 1997; O'Hanlon, 1996; Zuber-Skerritt, 1996) using an N of one (a case study). A common focus of action research is to promote a self-reflective analysis that can improve teaching practice and our understanding of practices (Kyle, Linn, Bitner, Mitchell, & Perry, 1991; O'Hair, 1995). This study involved a cycle of four steps: planning, enacting, observing the plan, and reflection (Carr & Kemmis, 1986).

While a case study has been applied to both quantitative and qualitative research methods and is itself not a methodology, a "qualitative case study is characterized by the main researcher spending substantial time, on site, personally in contact with activities and operations of the case, reflecting, revising meanings of what is going on" (Stake, 1994, p. 242). We chose a case study because we were interested in describing and interpreting the personal constructions of the college professor and his co-researcher as the professor examined his practice in the context of infusing innovation in his practice. A qualitative case study enables researchers to develop an in-depth narrative which provides a framework from which other teacher researchers can reflect on their experiences and which can inform future research (Romberg, 1992). For this study, the case is bounded by a unit of analysis that provides guidance on what is relevant and not relevant (Merriam, 1988; Ragin & Becker, 1992). The unit of analysis is the interdisciplary (mathematics and science) innovation of the one semester class.

The symbolic interaction theoretical stance makes the assumption that social reality is a social production (Blumer, 1969; Denzin, 1978). Meanings are constructed by humans through interaction; meanings are not inherently linked to inanimate objects or events. A central premise is that inquiry must be grounded in the empirical environment under study (van Sickle & Spector, 1996). This theoretical position places emphasis on the social construction of meaning in a culture through viewing the process of how individuals define and interpret each others acts. By carefully examining individual's interpretations of each others acts assertions are made as to how the individual's interpretations of each other sustain or transform the way they view their culture which guides they way they act and interact (Woods, 1992).

In this study, the symbolic interaction theory provided guidance for the roles of the researchers and the interpretative domain of the study (Goetz &

LeCompte, 1984). Since the researchers held the belief that their research was "a social production symbolically negotiated between the researcher and participant" (p. 57) explicitly revealing the purpose of the research to the participants and maintaining an openness of mind regarding interpretations of the participants' beliefs and actions complemented the action research methodological approach. Communication between the researchers and with the participants regarding subjective viewpoints became imperative to conduct in order to engage in meaning making within a group, the essence of symbolic interaction. Qualitative research assumes there are multiple realities constructed as a function of personal interaction and perception (Merriam, 1988). Respondent validation was desired as evidence of ongoing active communication between the researchers and the participants.

The professor, who was engaging in a prolonged semester long self-study of his teaching practices, believed that the symbolic interaction theoretical stance supported the case study methodological approach. He also believed that it complemented a tenet of his philosophy of teaching which encouraged being intellectually honest with his teacher candidates regarding an analysis of the teaching of science. Since he expected to be a learner in this action research study, symbolic interaction supported him in a researcher role that allowed him to focus his attention on interpreting his prior self and his present self as a consequence of his understanding of the events and the participant perspectives throughout the study's duration (Blumer, 1969).

Data Sources

Content Instruments. We used two instruments to assess the prior science knowledge of the teacher candidates enrolled in the science methods course. The GALT was used to assess process skills; a 60-item "Science Content Diagnostic" was crafted by the researchers from existing items in the literature (Gega, 1986) that aligned with the K-12 content recommendations made in the *National Science Education Standards* (1996). This instrument was divided into three sections (20 items each) that assessed a select knowledge in physical science, life science, and earth science. Table [] includes sample items for inspection.

Observations. Roth-McDuffie observed the science methods class on several occasions throughout the semester-long class. The observed classes were video-taped for later analysis. Whenever the students were working in groups, the observations focused on the MCTP teacher candidates. In addition, McGinnis videotaped the MCTP teacher candidates' and all non-MCTP teacher candidates' majoring in mathematics and science "Science Investigations" poster displays. These displays contained the results of a consumer science investigation presented in graph and textual form.

Interviews. Roth-McDuffie conducted semi-structured interviews with the six MCTP teacher candidates in the course. In addition, four non-MCTP teacher candidates in the course with concentrations in mathematics or science also agreed to be interviewed. The intent was to compare the MCTP teacher candidates' interview responses with the responses of these four non-MCTP teacher candidates with similarly strong backgrounds in mathematics and science but who had not taken MCTP reformed-based content classes. The interviews were semi-structured in that we used a protocol (see Appendix 1) for each interview, and Roth-McDuffie asked additional probing questions to clarify and/or pursue the participants' ideas. The interviews were conducted at the beginning and the end of the semester in groups of two or three. We opted to use small group interviews with the intent of providing a more conversation-like atmosphere which would allow one teacher candidate's comments to encourage the others to share additional thoughts. This strategy was consistent with the interactionist perspective in that it allowed the participants to clarify and develop their thoughts and responses in an environment similar to that of their classroom learning environment.

At the beginning of the semester, the teacher candidates were grouped in pairs with the MCTP teacher candidates interviewed separately from the non-MCTP teacher candidates. During the semester one of the four non-MCTP teacher candidates dropped out of the methods courses, and consequently, three non-MCTP teacher candidates remained in the comparison group at the end of the semester. To maintain consistency between the MCTP and the non-MCTP interview groups, we decided to conduct the final interviews in groups of three (again, with the MCTP teacher candidates interviewed separately from the non-MCTP teacher candidates). Throughout both sets of interviews, Roth-McDuffie ensured that all participants were provided the opportunity to contribute to the conversation. Each of the group interviews lasted approximately 30 minutes.

In addition to the semi-structured interviews, McGinnis conducted an open-ended, informal group discussion with the MCTP teacher candidates in the science methods class. The group discussion focused on ideas about make connections between mathematics and science in teaching and learning. The discussion was prompted with the initial question, "What attempts have you observed your science methods professor making connections between mathematics and science in your science methods courses?" and from that prompt a conversation transpired. Roth-McDuffie video-taped and, in addition to McGinnis, participated in the discussion.

Artifacts. The teacher candidates' products for the science methods class were collected for analysis. This included their weekly journal entries, written asssignments, and poster displays.

Refer to Table [] for summary of these sources of data.

Class Evaluations. Three previous official student class evaluations of the professor's elementary science methods class were item compared with the study class's responses on the end of the semester class evaluation. Table [] contains these class evaluations.

Trustworthiness of the data. Criteria to enhance the trustworthiness of the data analysis were based on ways described by Eisner (1991), Elliot (1991), Erickson (1986), Feldman (1994), and Guba & Lincoln (1989). These methods involved the qualitative warrant checks of long-term observation in a setting, collection of data from multiple sources, active search for counter examples, and the triangulation of data.

Contextual Setting And Participants

The Science Methods Class. The three-credit elementary science methods course examined in this study was taught in the fall semester, 1997, at the University of Maryland, College Park. At this university, senior education students enroll in "Blocks," a cluster of five content methods courses (mathematics, language arts, reading, social studies and science) all of which meet for one hour and fifty minutes one day weekly. The science methods course is the only exposure to science education in the elementary teacher candidates' program. In addition to classes at the University, students spend 2 full days each week in a field-based, public school placement. The field placements for non-MCTP teacher candidates were with regular classroom teachers in public elementary schools in the metropolitan region in which the university is located. The field placements for the MCTP teacher candidates were with specially trained MCTP cooperating mentors in upper elementary and middle level public schoos in the metropolitan region in which the university is located.

The science methods class was taught in a manner consistent with the education philosophy of the professor. In McGinnis's case, he chose to place emphasis on the construction of science content in conjunction with knowledge construction in science education theory. Science education topics typically that form the substance of the course include: concept mapping; the nature of science and science teaching; inclusive science education practices; the fair test; the learning cycle; science process skills; safety; alternative conceptions; alternative assessments; science talks; and science-technology-society. In practice, teacher candidates in McGinnis's class begin each class in small cooperative learning groups that engage in a student-centered, problem-based science learning activity that serve as a referent during subsequent pedagogy discussions facilitated by the professor. The activities are taken from existing sources, such as "Moon Gazing" (Schatz, 1991), or instructor created, such as an investigation of the causes of middle ear infections (McGinnis & Graeber, 1994). The activities are selected to represent different grade levels, all the sciences, and connections with other disciplines, particularly mathematics. McGinnis facilitates discussions by posing questions that unpack the pedagogical implications inherent in the activities. His goal is to assist the teacher candidates in constructing a schema of science teaching practice consisting of the categories "Science Content," "Pedagogical Content Knowledge," "Curricular Knowledge," "Attitude," and "Context." General questions, such as "What science content was taught/learned in the activity?" and "What pedagogical strategies were used to teach/learn that content?" serve as conversation catalysts. The professor also serves the role of an expert of science education research that is relevant to science education topics, such as the fair test, concept mapping, and inclusive science education practices. The teacher candidates take the lead in several class sessions in which they engage in a type of peer coaching in which they demonstrate and discuss with their small cooperative learning teams science lesson plans they developed for use with elementary students. In addition, the teacher candidates make presentations near the end of the semester in which they discuss a consumer science inquiry they facilitated that semester with young learners in a school setting.

The teacher candidates are assessed by their ability to research a science content topic; to interview young learners on their conceptions of the topic and report their findings in a concept map; to carry out instruction (and reflect on that experience) with a small group of elementary students in a public school setting; to carry out a scientific investigation and present it to the class in a poster format; and to write an end of the semester essay in which they delineate their perception of the theoretical structure of science education and provid practical examples on how to enact that schema in an elementary school setting.

Participants. As previously mentioned, participants in this study included the professor of the science methods class, a coresearcher, and the thirty teacher candidates in the course. Special focus was on six teacher candidates participating in the MCTP and four non-MCTP teacher candidates with concentrations in mathematics or science. We wanted a comparison group of non-MCTP teacher candidates that was most similar to our MCTP group in terms of prior content preparation, so we selected four who were concentrating in mathematics or science elementary education (2 mathematics, 2 science). One of the participants (science concentration) in the non-MCTP comparison group dropped out of the methods block before the end of the semester. Refer to Table [] for a more detailed of each of these nine teacher candidates.

Planning To Study McGinnis's Teaching

In preparation for my innovation to make connections between mathematics and science in the science methods course, Roth-McDuffie and I conducted a review of the literature. Our intent was to survey what was promoted as a rationale for making connections between the disciplines and what theorists understood about attempting such an innovation. In particular, two areas were examined: professional associations' call for mathematics and science integration and theoreticians' conceptualization of mathematics and science integration.

Professional Associations' Call for Integration of the Disciplines. From our review of the literature, we learned that professional associations concerned with the teaching of mathematics and science have long called for the integration of the disciplines. Prominent among these associations is The School Science and Mathematics Association, the National Council of Teachers of Mathematics (NCTM), and the American Association for the Advancement of Science (AAAS). Indeed, faced with a burgeoning body of work on the integration of the two school disciplines, *School Science and Mathematics* in 1905 decided it was necessary to publish a bibliography of the literature on that topic to assist interested professionals. This interest in integrating mathematics and science continued in these associations throughout this century. Currently, this interest has manifested itself strongly in the mathematics and science education reform documents promoted by the NCTM, AAAS, and the National Research Council (NRC). Influential documents such as *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), *Science for All Americans* (Rutherford & Algren, 1990), *Benchmarks for Scientific Literacy* (AAAS, 1993), and most recently, *National Science Education Standards* (NRC, 1996) all promote linking the teaching of the two disciplines. For example, Program Standard C in the *National Science Education Standards* (NRC, 1996, p. 214) states a science perspective of this linkage:

> The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics....Science requires the use of mathematics in the collection and treatment of data and in the reasoning used to develop concepts, laws, and theories.

[{Perhaps this suggestion is too much to take on for changes before the Jan. presentation, and we might want to consider the below suggestion for future revisions of the paper for publication. However, the lit review might be stronger, sending a more coherent message, if it were organized thematically, rather than chronologically. For example, I see the literature breaking into the following three themes:

Reasons to integrate: Dewey; McBride; Roth; Stuessy; Lehman (1994); and Austin, et al.

Models of integrations: Brown and Wall; EDC; Bagheri and Kretschmer; Berlin; Steen; Dossey; and Lonning and Defranco.

Perceptions of/toward integration: Lehman and McDonald; and Lehman (1994).}]

Theoreticians Conceptualization of Mathematics and Science Integration. We found Berlin's (1991) comprehensive bibliography on the integration of mathematics and science particularly helpful to begin our search. We were surprised to learn from Berlin's review that research had played a subsidiary role in the literature on this topic. In discussing her review of the literature, Berlin (1994) stated there existed a "marked paucity of research documents" (p. 32) with only 41 of the 555 citations relating to research. She stated there was a need for "conceptualization and additional research on integrated science and mathematics in teaching and learning" (p. 4). In a more recent, comprehensive review of the literature on this topic, Huntley (1997) also found a dearth of research on integrating mathematics and science in education. Committed to guiding our teaching innovation by insights from scholarship, we devoted considerable attention to reviewing the relatively few theory-based articles on this topic. What follows is a summary of the articles arranged by date, from oldest to most current, that informed us.

In 1916, John Dewey engaged in one of the earliest discussions about integrating all disciplines in teaching and learning and about learning through meaningful activities. Dewey's rationale for the teaching of subject matter in an integrated manner was founded on his belief that there was too much subject matter in the respective disciplines to be mastered by a separate study of each in school settings. He states:

> The "course of study" consists largely of information distributed into various branches of study, each study being subdivided into lessons presenting in serial cut-off portions of the total store. In the seventeenth century, the store was still small enough so that men set up the ideal of a complete encyclopedic mastery of it. It is now so bulky that the impossibility of any one man's coming into possession of it all is obvious. But the educational ideal has not been much affected (p.220).

Furthermore, Dewey thought that the disciplines would by necessity be taught in an integrated manner if schooling were concerned with assisting learners to make sense of everyday experience that did not come separated into separate domains of study. He states:

> The teacher should be occupied not with subject matter in itself but in its interaction with the pupil's present needs and capacities. Hence simple scholarship is not enough. In fact, there are certain features of scholarship or mastered subject matter - taken by itself - which get in the way of effective teaching *unless* the instructor's habitual attitude is one of concern with its interplay in the pupil's own experience (p. 215).

In regards to science Dewey thought that it was in particular danger of being distant from learners' everyday concerns if it were taught as a separate discipline. As he states:

> The fact that science marks the perfecting of knowing in highly specialized conditions of technique renders its results, taken by themselves, remote from ordinary experience - a quality of aloofness that is popularly designated by the term abstract. When this isolation appears in instruction, scientific information is even more exposed to the dangers attendant upon presenting ready-made subject matter than are other forms of information. (p. 223).

Brown and Wall (1976) in an influential article discusses a continuum model of integration that emerged from the Cambridge Conference that focused on the integration of mathematics and science. They present the integration of mathematics and science in terms of common processes and describes the six areas of learning that are common to mathematics and science that can be dealt with in a hands-on laboratory setting. The areas are: (1) sorting and classifying; (2) measuring; (3) using spatial and time relationships; (4) interpreting data; (5) communicating; and (6) formulating and interpreting models.

In *Goals for the correlation of elementary science and mathematics: The report of the Cambridge Conference on the correlation of science and mathematics in the schools* (Education Development Center, 1976), a model of relating science and mathematics in a curriculum is presented. The report states that,

A good curriculum comprises units and activities which relate the science in mathematics in different ways, which could be described as: mathematics for mathematics; mathematics for science; mathematics *and* science; science for mathematics; and science for science. (p. 19).

Lehman and McDonald (1988) present a study designed to assess whether an integrated approach to teaching mathematics and science would change preservice teachers' perception toward integrating the two disciplines. Also, the researchers compared preservice teachers' (in the integrated program) and practicing teachers' perceptions of mathematics and science. They found that preservice teachers increased their awareness of curricular materials for math/science integration and believed that integration mathematics and science is a preferable method for teaching. The science student teachers began the semester thinking that their high school teachers integrated mathematics and science and ended the semester thinking that they did not integrate the disciplines. Lehman and McDonald posited that this change shows that the student teachers developed a more sophisticated definition of integration after starting the semester with an oversimplified definition of integration. However, they also found that mathematics student teachers changed their thinking in the reverse direction. They started out saying that their high school mathematics teachers did not integrate the two disciplines but ended saying they did integrate them. Lehman and McDonald attribute this change to possible recognizing some activities as integrated under a more sophisticated understanding of integration, or possibly recalling some activities that they previously had not.

Among practicing teachers, science teachers indicated that they integrated mathematics and science more often than did mathematics teachers. Although mathematics teachers believed that integrating is a preferred teaching method, less than half of the sample indicated that they made attempts to integrate the two disciplines. The mathematics teachers were concerned about the time required to integrate the disciplines. From these findings, Lehman and McDonald contend, "Their concern about time may also be indicative of a belief that integrating mathematics and science would require their adding science into what they perceive as an already crowded curriculum" (p. 648).

Bagheri and Kretschmer (1991), described a model and their teaching experiences integrating science and mathematics methods courses and the student teaching. The four main features of the model are as follows: (1) the same professor that teaches the methods course also supervises the teacher candidate in student teaching; (2) emphasis on curriculum development and evaluation; (3) focus on teacher candidates "growth in their capacity for analytical and evaluative work" for all aspects of teaching including "assessment of broader educational issues, observing in classrooms, or reviewing curricular materials" (p. 18); (4) "nurture teacher candidates as reflective practitioners who make pedagogical decisions in light of what they know of subject matter, learners, social contexts, cultures, and the purposes of an elementary education" (p. 18).

As previously mentioned, Berlin (1991) conducted an exhaustive review of the literature on the topic of integrating mathematics and science. Authors included classroom teachers, teacher educators, curriculum developers, and educational researchers. Most helpful for our purposes of preparing teacher candidates to make connections between mathematics and science was her finding of how science and mathematics had been most commonly presented in attempts to integrate the two disciplines. She states:

> The science processes of classifying, collecting and organizing data, communicating, controlling variables, developing models, experimenting, inferring, interpreting data, measuring, observing, predicting, and space-time relationships were most frequently cited in the instruction literature. The most frequent mathematics concepts/skills mentioned or implied include: angular measurement, estimation, formulas and equations, fractions, function, geometry, graphs, modeling patterns, percentage, probability and statistics, problem solving, ratio and proportion, and variable (p. 4).

McBride (1991) provides a brief history of the integration efforts made to link mathematics and science. In a synthesis of the literature, McBride discusses a rationale for integrating mathematics and science. The four reasons given are:

> (1) Science and mathematics are closely related systems of thought and are naturally correlated in the physical world. (2) Science can provide students with concrete examples of abstract mathematical ideas that can improve learning of mathematics concepts. (3) Mathematics can enable students to achieve deeper understanding of science concepts by providing ways to quantify and explain science relationships. (4) Science activities illustrating mathematics concepts can provide relevancy and motivation for learning mathematics (pp. 286 - 287).

McBride identifies several research questions that need to be addressed. One of these questions is "How can preservice teachers be prepared so that they can integrate science and mathematics instruction when they can become teachers?" (p. 288). Also, McBride identifies five problems of integrating that must be addressed: (1) math and science are currently organized and taught as separate subjects in most schools; (2) teaching math concepts through science activities requires more time; (3) classroom management can be more complicated when using integrated activities as opposed to whole class mathematics instruction; (4) mathematics teachers often do not have the science materials necessary; (5) few teachers have access to or awareness of integrated curriculum materials. McBride lists and provides a brief description of commercial resources, professional organizations, projects, and other resource materials available to support teachers. Among several recommendations, McBride states, "Teacher educators must implement ideas of integration into their methodology classes. Preservice teachers must be given both rationale and methodology for integrating science and mathematics instruction" (p. 290).

In light of theories on constructivism and cognitive apprenticeship that suggest that school curriculum should integrate subject matter with real-world problems, Roth (1993) provides an example of mathematics and science learning being integrated through a case study of a high school physics student. Roth demonstrates the benefits of linking mathematics and science (with the use of technology) through an in-depth analysis of one students' learning.

Stuessy (1993) discusses the rationale behind integrating mathematics and science in a methods course and describes the course and its development. The similarities between the disciplines is discussed in terms of both content knowledge and pedagogical knowledge, and in terms of the reform movements for both mathematics and science. The instructors of the methods courses noticed, in particular,

> the synergistic relationship that existed between the knowledge domains of mathematics and science in problem-solving situations, with mathematics often providing the language for scientific phenomena, and science providing a natural context for the learning of particular mathematics concepts (p. 57).

Stuessy used the following data sources as indicators of the relevance of the course in preparing preservice teachers to teach mathematics and science: (1) a multiple choice measure of students' self-efficacy in teaching mathematics and science (the STEBI and the MTEBI); (2) students performance data (measured by 3 portfolio grades and a final examination); (3) students' responses informal exit interviews and course evaluations. These data sources indicated that the integrated methods course was very successful. Scores on the self-efficacy instruments "showed significant positive gains in students' beliefs about themselves as successful teachers of mathematics and science" (p. 61). Also, the students portfolio scores showed higher levels of performance on teaching related tasks. Finally, students' indicated a high level of satisfaction with the course.

Steen (1994) discusses possible ways to integrate mathematics and science. These methods include: (1) using mathematical methods in science; (2) using science examples and methods in math instruction; (3) teaching math entirely as a part of science; (4) teaching science entirely as a part of mathematics; (5) employing math methods in science and science methods in math, coordinating both subjects. Steen describes each of these options and uses this description to make the point that while mathematics and science can contribute to each other, the two disciplines are "fundamentally different enterprises" (p. 9). He states that "science seeks to understand nature, [and] mathematics reveals order and pattern" (p. 9). He concludes, therefore, that an effective educational program must teach students the ways not only in which mathematics and science are similar, but also the ways they are different. Steen questions whether it is possible "to teach an entire curriculum that integrates science and mathematics" (p. 10). He believes that it is not possible because science and mathematics teachers are not sufficiently prepared to understand mathematics and the multiple sciences within science (e.g., physics, biology, chemistry). To avoid this overwhelming constraint to successfully integrating mathematics and science, Steen suggests that instead of attempting to integrating content, practitioners should integrate instructional methodologies (e.g., exploratory, investigative, and discovery learning).

Dossey (1994) reviews models for the integration of mathematics and science: (1) a simultaneous model where ties are made between the content in math and science courses; (2) a braided model where content from the disciplines are viewed as strands to be visited every year; (3) a topical model where the curriculum focuses on specific topics; (4) a unified model where unifying ideas are used to examine and relate concepts, principles and procedures from both disciplines (e.g., sets, functions, and structures); (5) a full interdisciplinary model which "completely merges the disciplines and draws from each when content is needed to move the topic forward" (p. 14). Dossey notes that while we have many examples of the simultaneous model taking place in our schools, the little contact between teachers prevents teachers from making rich ties to integrate mathematics and science. Moreover, Dossey concludes that careful development of examples of the other models have not been attempted. Dossey suggests that the recently developed Standard documents in mathematics and science may provide the support to achieve integration. However, he lists several barriers and actions that need to be taken to overcome these barriers: (1) curricular materials need to be developed; (2) assessment instruments need to be developed to appropriately measure progress in an integrated curriculum; (3) teacher education programs need to change to prepare teachers to teach integrated curricula; (4) public relations efforts need to be initiated to educate the various constituencies involved in education.

Lehman (1994) presents a study that extends the previous work of Lehman and McDonald (1988). Lehman summarizes the reasons for integration as:

> (1) to increase students' achievement in both disciplines; (2) to be motivational and produce more positive attitudes towards mathematics and science; and (3) to emphasize relationships between concepts resulting in more meaningful learning. (p. 58).

The purpose of Lehman's study was to understand how practicing and preservice teachers perceive the idea of integrating mathematics and science. Lehman administered an eight item questionnaire to 161 undergraduate elementary education majors and 60 elementary teachers. From an analysis of the survey results, Lehman detected three findings. First, preservice teachers were more likely to prefer integrating mathematics and science in teaching than practicing teacher (75% of preservice compared to 50% of practicing). Second, less than 50% of the practicing teachers believed they had sufficient background to integrate mathematics and science. Of the preservice teachers, approximately one-third believed they had sufficient background to integrate. Third, 41% of practicing teachers believed that there is not enough time to integrate mathematics and science as compared to 12% for preservice teachers. Thus, for many practicing teachers, integrating is seen "as another add-on topic" (p. 62). Included among Lehman's recommendations are the following: (1) preservice elementary teachers should receive instruction in mathematics and science integration and should have opportunities to teach integrated lessons in field experiences; and (2) alternative models for integrating in preservice and inservice training should be explored.

Lonning and De Franco (1997) propose a continuum model of integration as a tool for curriculum development and for modifying lessons to enhance math and science connections. To effectively integrate mathematics and science in a lesson, content from both areas must be at the appropriate grade level (part of the curriculum for a specified grade level). The authors content that using the curriculum is helpful in answering the following important questions:

> (1) What are the major mathematics and science concepts being taught in the activity?
>
> (2) Are these concepts worthwhile? That is, are they the key elements of the curricula and meaningful to students? Reflecting on these questions may change the context and the nature of the activity and in the process move the activity along the continuum toward a balanced integrated activity. (p. 214).

The authors caution that not all mathematics or science concepts can or should be taught through integration, and we should focus on the question, "'How can the concepts best be taught' rather than 'How can they be integrated?'" (p. 215).

Austin, Hirstein, & Walen (1997) examined whether students participating in a high school curriculum designed to implement the NCTM *Standards* and integrate mathematics and science had better attitudes and achievement than control classes. They found significant attitude improvement in the experimental students' mathematical confidence, no significant differences between experimental and control classes PSAT scores, and significant differences on the a problem solving test at the end of the year (favoring the experimental students). "These results suggest that a Standards-based curriculum can improve students' mathematical attitude and problem-solving skills" (p. 45).

Enactment of Plans/ Observation. McGinnis structured science methods for elementary teachers, EDCI 372A, along three intellectual themes: constructivism, multiculturalism, and curriculum connections. The intent was to foster a learning community in which the elementary teacher candidates would reflect on these constructs as they developed skills, knowledge, and dispositions appropriate for the teaching of elementary science.

The version of constructivism emphasized was a fusion between ideas voiced by von Glasersfeld (1989), and Brooks and Brooks (1993). This meant that classroom science knowledge was represented as being constructed by individuals who actively participated in group problem solving learning experiences. Knowledge claims were evaluated as to their fit with evidence and were characterized by their openness to change as determined by additional information. The focus in science methods was not on finding the truth but on building testable theories.

The version of curriculum connections emphasized was adapted from *Goals for the correlation of elementary science and mathematics: The report of the Cambridge conference on the correlation of science and mathematics in the schools* (Educational Development Center, 1969) and Brown and Hall (1976) as presented in Lonning and DeFranco (1994). Efforts to connect science and mathematics were evaluated along the continuum suggested by Brown and Hall. Points on the continuum included "Independent Science, Science Focus, Balanced Mathematics and Science, Mathematics Focus, and Independent Mathematics." Considerable consideration was placed on the type (and appropriateness) of making connections between science and mathematics in specific lessons.

The following are activities/circumstances that were unique to this course during the study period and were facilitated by participation in/connection with MCTP:

1. McGinnis was able to recruit students with an area of emphasis in mathematics (4 teacher candidates) or science (7 teacher candidates) in addition to 9 MCTP teacher candidates. Twenty of the 30 students had either mathematics or science as an area of emphasis. Typically, the section includes at most 7 or 8 teacher candidates with mathematics or science as an area of concentration.

2. McGinnis taught a demonstration lesson derived from curricular development work done by the MCTP faculty, "The Island of Earf" (McGinnis & Graeber, 1994). This module makes links between mathematics and science as the teacher candidates participate in a simulation activity as members of health clinics charged with determining the causes and treatment of ear infections on an island.

3. McGinnis focused on the cognitive/constructivist major view of teaching. He began the semester modeling how the teacher candidates could teach young learners the phases of the moon in a problem-based, interdisciplinary (mathematics and science), cooperative learning and technology rich manner. He continued modeling exemplary pedagogical practices throughout the semester in many other learning activities. The direction of innovation in this class was certainly set by MCTP.

4. McGinnis used the text *The young child as a scientist: a constructivist approach to early childhood education* (Chaille & Britain, 1997) as one text to support the constructivist perspective of the MCTP; he used *Science in the Multicultural Classroom* (Barba, 1998) to support the MCTP perspective on diversity; he used *National Science Education Standards* (National Resource Council, 1996) and *Benchmarks* (American Association for the Advancment of Science, 1990) to support the emphasis on the standards movement in science education, and he used *Talking Their Way Into Science* (Gallas, 1995) to support the emerging concern for classroom discourse in science education.

5. Reflection on key ideas and conceptual change was emphasized. The past reports of the value of journaling, by both students and MCTP instructors as well as

McGinnis's prior experiences in more routine courses the previous semester led him to implement journaling. Students wrote journal entries. On the final exam students were asked to reflect on how their major concepts (big ideas) that they held about teaching science have been challenged or viewed in a different light.

6. McGinnis made more effort than usual to have performance based evaluation activities. He used a modified version of Peer Coaching (Neubert, 1988), an MCTP mentor teacher advocated method, to guide the teacher candidates' three peer conversation experiences (on physical science, life science, and earth science). The majority of the class assignments were based on activities and data collected in the teacher candidate's field-based placements in elementary/middle schools. They all were evaluated (first by the teacher candidates themselves then by the professor) using rubrics that the teacher candidates assisted in developing.

Analysis. We collected and analyzed the textual data through the use of the qualitative technique of analytic induction to construct patterns of similarities and differences between the professor's and his co-researchers perceptions (Bogdan & Biklen, 1992; Gee, 1990; Goetz & LeCompte, 1984; LeCompte, Millroy, & Preissle, 1992). In analyzing the data and looking for patterns, we used both the emic and etic perspectives. The etic perspective imposes the researchers' theoretical framework on the data; while the emic perspective uses the participants' own words to develop the narrative (Van Maanen, 1995). We collected the quantitative data through the use of two instruments that measure science process and content knowledge. These were analyzed using non-parametric statistics.

Findings

Assessing the Teacher Candidates' Science Content Knowledge

To answer our first research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the science content knowledge they bring to their science methods class?") we administered two instruments at the beginning of the semester. Refer to the "Sources of Data" section for a full description of each content instrument. In analyzing these data we performed the Mann-Whitney U Test using the SPSS version 6.0 statistical analysis software package. The Mann-Whitney U Test is commonly used in place of a t-test for the equality of two means when sample sizes are small and correspondingly the assumption of normality is questionable (McGhee, 1985). This test is regarded as "one of the most powerful of the nonparametric tests for comparing two populations" (McGhee, 1985, p. 509).

In determining our two groups, we compared the MCTP teacher candidates with the following groups: (1) all of the other teacher candidates in the class; (2) the teacher candidates who had a science concentration; and (3) the teacher candidates who had a mathematics concentration

The results from the Mann-Whitney U analysis of the GALT scores are shown in Table []. (Note: a higher rank signifies a better score.) The results show that the MCTP teacher candidates performed significantly better than the other teacher candidates in the class on the GALT at the 0.10 level of significance ($p=0.08$). While the MCTP scores, as a group, were better than the other sub-groups (i.e., science and or mathematics concentration) a significant difference did not exist between the MCTP teacher candidates scores and any of the sub-groups. Thus, the MCTP teacher candidates performed as well as either the mathematics concentration or the science concentration teacher candidates, and the MCTP teacher candidates performed better than the other teacher candidates as a whole.

The Science Diagnostic Instrument scores were analyzed as follows: (1) total score; (2) physical science score; (3) life science score; (4) earth and space science score. The results from the Mann-Whitney U analysis for these scores and for the various groups described above are shown in Table 2. The total score results indicate that the MCTP teacher candidates performed significantly better that their classmates on the Science diagnostic instrument ($p=0.05$). In addition, the MCTP teacher candidates' total scores were significantly higher than the mathematics concentration teacher candidates' scores ($p=0.03$). In comparison with the science concentration teacher candidates' scores, the results show that the MCTP scores are quite consistent with the science concentration scores.

In examining the sub-scores in the areas of physical, life, and earth and space science, we see that the MCTP teacher candidates' scores are significantly higher than the mathematics concentration teacher candidates for both the life ($p=0.03$) and the earth and space sciences ($p=0.03$) sub-scores. In addition, the MCTP teacher candidates performed better than their classmates as a whole on the earth and space science section of the instrument ($p=0.02$). For the remaining sub-score comparisons, the MCTP teacher candidates' scores were not significantly different.

Given that the MCTP teacher candidates were prepared with a focus on both mathematics and science content areas, these results indicated to us that the dual focus and the MCTP content professors commitment to a more problem-centered, student-centered pedagogy did not diminish the scientific knowledge gained as compared to the teacher candidates who focused only on science in more traditionally taught science content classes. Moreover, the MCTP teacher candidates appear to have a stronger scientific knowledge base than the other teacher candidates who focused only on mathematics, and also stronger than the teacher candidates who focused on neither mathematics nor science.

Understanding the Beliefs and Perceptions the Teacher Candidates Brought to the Science Methods Course

To answer our second research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions they bring to their science methods course concerning [a spectrum of areas]") we analyzed the data we collected from the beginning of the semester teacher candidate interview. What follows are assertions we generated from a careful reading and comparision of all the participants' responses to the interview questions. These assertions are presented in the order of the sub-sections of the second research question. Included in each are exemplar comments from the participants that support the claims made by our assestions.

a. Content preparedness to teach elementary students. *The MCTP teacher candidates were distinguished from the other teacher candidtates by expressing that preparedness to teach young students science content required their being taught content in a manner that modeled good practices. However, as a result of being taught science content by MCTP faculty in a constructivist manner, the MCTP teacher candidates recognized that a high level of comfort with science content was required. Consequently, the MCTP teacher candidates tended to express they felt less prepared as compared with the responses of the non-MCTP teacher candidates who were taught content in a lecture-based manner. The non-MCTP teacher candidates expressed a somewhat naive confidence of their content preparedness.*

MCTP Teacher Candidate Beliefs and Perceptions. The distinguishable feature of the MCTP teacher candidates' comments on content preparedness was that they believed their MCTP professors taught content in a manner that modeled good pedagogy, and they could emulate this approach with young learners. They believed this approach promoted lifelong retention of content.

Jennifer:

I think, especially the MCTP classes, we've seen the type of instruction and we've gotten to experience firsthand the way that we want to teach math and science, so that it's not the boring memorization, you know, do that problem 10 times, or just memorize the biology and whatever. And I think that we've had a stronger base of the content because it has been taught that way; I think I've learned it more.... I mean, it was more of a displaying of that type of teaching method. There weren't real methods taught, you know, about how to teach the subject, but I think more of a display of that type of teaching. (Interview, September)

Aubrey:

I think absolutely, totally my Physics 117 was incredible. I think to this day I still have a pretty good knowledge base of what happened in that class and can explain things with some, you know, some level of knowledge and confidence. But I just finished [non-MCTP] chemistry this summer, two sessions, and I probably couldn't pass any of the exams if they were given to me right now, and that was only about a month ago. (Interview, September)

Bob:

I'm not completely confident in math. The content in science, I do not know. I just wonder if I remember what I should and how difficult it will be when I get to doing a lesson plan or a unit. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions. A distinguishable feature of the non-MCTP teacher candidates' comments on content was a perception that while they believed that they had gained a sufficient body of science content knowledge, it had been learned in isolation from a good model of how to teach young students.

Patty:

Science, I would say I am pretty prepared for the elementary level, yes. Middle school, the courses I took are enough--enough I think to probably prepare for middle school. I don't know how much I have retained to be able to just go in there right now. I mean, I would definitely have to review. (Interview, September)

Kevin:

I had always felt that we had gone through and learned the science content, but that I was never taught how to teach until I got into these classes [method block]. Now I feel quite assured that I will know strategies and ways to deal with teaching that I had felt was really not touched on at all in previous content courses. (Interview, September)

Kelly:

I would agree that I am okay with the science content, but how to teach it up until right now I am not at all confident. (Interview, September)

b. A vision of an appropriate science learning environment for elementary students. *The MCTP teacher candidates expressed a vision of an elementary science learning environment in alignment with the reform movement (student-centered and problem-based, with an emphasis on students' prior knowledge) that they believed was modeled by their MCTP science content professors. They also could contrrast this reform-based vision with a traditional, lecture and textbook-based science content environment. The non-MCTP teacher candidates expressed dissatisfaction with a traditional learning environment based on teacher lecutre [(lecture)], but could not express an alternative vision of good teaching for elementary science students except for the increased use of labs involving equipment and manipulatives. Moreover, when they referred to using equipment and manipulatives, the non-MCTP teacher candidates did not indicate that they had developed a vision for how they would use these things or for what purpose.*

MCTP Teacher Candidate Beliefs and Perceptions. Drawing on their recent undergraduate experience learning science content in MCTP classes, the MCTP teacher candidates expressed a well-developed vision of an elementary science learning with specific examples of their vision. The learning environment that they described included inquiry, cooperative learning, a concern for students prior knowledge, the teacher as a facilitator, and a commitment to achieving equity between males and females. Furthermore, they indicated they had developed personal theories/rationales for why these modes of learning are appropriate for young learners.

Karen:

I guess I kind of imagine a classroom setting with the students in groups of four or five; lots of manipulatives at least in the beginning part of the lesson, like an introduction to geometry with the cubes or something like that. And what I've learned, and am finding more and more important, is the discussion taking part in mathematics and science. That it helps the kids understand the concepts more clearly, and it also gives the teacher a chance to assess that way rather than as a quiz with multiplication tables and that kind of stuff. You can hear what they're talking about and see what kind of level they're at, so I definitely would like to emphasize discussion. "How did you get that answer?" Or if two people got the same answer but they did it differently, "Show how you did it," you know, more like a process than just having the right answer. (Interview, September)

Bob:

I guess I envision a classroom where the students are having so much fun and are so interested that they can't help but learn from each other, and share. I guess my ideal is, I'm somehow gonna be able to make that happen and make it so interesting that they'll want to know about probability, or division, or whatever it is. And I think by doing that, you allow the students to have fun with manipulatives, and interact with each other. I think of the way I am now. Just the way I learned science and mathematics, it was not the right way to apply it. It was more memorization and stuff. I hope to be able to keep that in my mind as I teach. (Interview, September)

Aubrey:

Having experienced the MCTP style, like, constructivism, it's kind of a new thing taught in front of us.... I think I do have a little bit of an advantage by having that..... (Interview, September)

Stephanie:

My first class [in the MCTP] was hands-on with Dr. Layman [introductory physics]. That format is so different, but I feel like that class kind of prepared me for how I want to teach. (Interview, September)

Jessica:

I think learning content has to be non-threatening. I think the group work is good with a lot of hands-on materials. I think it should be something that it seems like it's a situation that is fair to both males and females.... My vision of my ideal science classroom, I would have lots of living things all around the class--animals, fish, plants, just all kinds of stuff all over the walls. I'd have all kinds of different areas that students can move to and explore and learn things, books that they can look at, things that they can look at, things that they are interested in, lab tables, lots of equipment. Just, really a student-centered, really nice environment where they would be learning by doing things hands-on. Group work-- manipulatives, experimenting, finding things out on their own. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions. In the context of their recent undergraduate experiences of learning content in a lecture-based manner that they beleived was inappropriate for young learners, the non-MCTP teacher candidates' alternative vision of good pedagogy for young learners was one based on instances of good teaching in their own K-12 educational histories or on brief field-based education experiences observing young students. These alternative visions were not thoroughly developed.

Anna:

As an elementary student, I always liked the practical experiments. Like, when I was in second through fourth grade I didn't speak much English, and with the experiments and laboratory work, I'd learn through observing the lab, the experiment, the actual experiment. I couldn't read or understand, so I only learned through observation. (Interview, September)

Patty:

I think in the elementary level, I think manipulatives are real effective. [pause] I've done a lot of one-on-one with kids. Most of my experience [as a parent volunter in an elementary school] has been with second grade, and I've done a lot of one-on-one or working in small groups, and it seems like it's much easier to show them using something than to just try and tell them, so definitely manipulatives is an effective way. (Interview, September)

Kelly:

That the kids are using manipulatives, that they're actually doing the work. Often, now I see teachers writing on the board, and the children are copying. (Interview, September)

d. Rationale for and intent to make connections between science and mathematics in elementary teaching. *The MCTP teacher candidates evidenced considerable reflection based on the firsthand MCTP experience of learning science and mathematics in a connected manner for a rationale making connections between science and mathematics. They intended to make extensive connections between the disciplines in their future practices. The non-MCTP teacher candidates were characterized by not having reflected on a rationale for making connections between the disciplines nor having experienced learning the disciplines in that manner except in cases where mathematics was used as a tool in science. They expressed a willingness to make connections between mathematics and science but based that connection solely on the use of mathematics as a tool. In addition, while both the MCTP and the non-MCTP groups seem to discuss mathematics as a tool for science when discussing what mathematics as a discipline brings to science, the MCTP group seems to recognize common processes of the disciplines (unlike non-MCTP group).*

MCTP Teacher Candidate Beliefs and Perceptions. The MCTP teacher candidates' brought to their science methods course the ability to articulate a rationale for making connections between science and mathematics based on extensive prior experience of learning the disciplines in that manner. Through their MCTP experiences, they perceived mathematics and science to be so intrinsically connected that they had difficulty conceiving teaching them as separate subjects. Their rationale included the belief that both disciplines could contribute, and in the case of mathematics, assist the other, in developing a better holistic understanding of an area of interest. They professed a shared intent to make extensive connections between the two disciplines in their future teaching practices.

Stephanie:

Well, I pretty much think that mathematics and science are interconnected. I mean, if you think about the formulas in science, you're learning all that in math, also.

Jessica:

I think that one of the reasons Stephanie might think that and that I might think that, too, is just because we've been learning it that way, for the past 4 years (I know I have anyway). And so I say, "Oh yeah, math just fits in with science, and science just fits in with math naturally. How would they not?" And maybe some people don't see that and don't emphasize it. I don't know if it's something that we have to emphasize so much and try and make a point of doing it because we're just so used to doing it anyway, and it's just going to naturally kind of fit in.

Karen:

Making connections keeps things as a whole, and you know, learning parts, and parts, and parts, and parts that is just a bunch of parts, but if you make connections all across the board, especially with math and science, because they relate so much, it just keeps everything like a nice package all wrapped up.

Jessica:

I think you can make connections between mathematics and science using calculators, graphing, all sorts of graphs, all kinds of graphs that you could do for different things in science. Doing different trials, and making graphs of your findings type things. I mean, math naturally comes out in science that way. For math activities, you could give them activities, too. An activity I had in an MCTP math class comes back to my mind. It was about learning about shadow lengths and how we could determine how the people in the past could determine that that the earth was round and the distance around the earth by a change in shadows. I mean, that's an example of a way that would relate science and math together, and you could do it in a math class, and kids might not think they were learning science, but they would be learning science just by measuring shadows and that sort of thing.

Aubrey:

I think mathematics and science can be connected largely by not calling it a math lesson or a science lesson. I think dealing with the topics and letting them flow into the different subjects sort of leads to an integration without forcing it. And questioning, open-ended questions, and probing questions that would lead them to kind of make those discoveries in their minds and draw their experiences from both together. I want to set up things so, like, if my units are more interdisciplinary, so then the connections, hopefully become obvious at least in a way that the kids are gonna feel like they can go home and say, "Mom, I did this today. This was math, but you know what? It was also science and it was really fun and important.

Stephanie:

You don't have to say, "Look, there is a interconnection between these two subjects." It's gonna come out naturally.

Non- MCTP Teacher Candidate Beliefs and Perceptions. The non-MCTP teacher candidates brought to the science methods course a restricted rationale for making connections between mathematics and science. While they voiced a willingness toward attempting to make connections between science and mathematics, they based the connection fundamentally between science and mathematics on mathematics use as a tool in science.

Patty:

Oh, this one I'll have to think about....I'm sure I could come up with lots of ways to tie them together, I just can't think of any right now.

Kevin:

I think it is important to make connections between mathematics and science. . There's quite a large connection between the two of 'em. You can always figure out science properties by doing the experiment, but then its usually the math that's used to prove them.... Hopefully I'll learn how to connect mathematics and science this semester [during the methods block].

Anna:

Usually, when you collect data from science, you're actually doing the math, because most of the experiments want you to find the average.

Kelly:

Well, I think it would be easier to show the connections going from science to math for me. To show that how--I can't think of an example--but when they've done an experiment and they had to, like, say write the results down, and they've made a graph or something and then you can connect that to the math.

e. the role of science methods in their teacher preparation program. *The MCTP teacher candidates brought to the science methods class an inclusive vision of teacher preparation program composed of a seamless linkage between their undergraduate content courses and their science methods course. As a result of being taught content in a manner that modeled good pedagogy, they had a vision of how they wanted to teach. However, they recognized that the science methods course was essential to teach them the skills and knowledge base to enact that vision of teaching. The non-MCTP teacher candidates brought to science methods a vision of content classes taught in a manner they believed was inappropriate for young learners. They saw the science methods as their first opportuity to gain skills in teaching science appropriately.*

MCTP Teacher Candidate Beliefs and Perceptions. The MCTP teacher candidates held the vision of science methods as performing an important next step role in their teacher preparation program by assisting them in enacting their vision of teaching content to young learners appropriately. They believed the primary purpose of science methods was to give them them the opportunity to develop the strategies and knowledge necessary to adapt what they previously observed their professors doing in science content classes to lessons for young learners.

[{Consider replacing, "adapt what they previously observed their professors doing in science content classes to lessons for young learners" with "create learning opportunities and environments similar to what they previously experienced in their MCTP content classes." Based on the below quotes and what I recall in the interviews, I am not sure that they expressed the idea that they wanted to teach 4 - 8 versions of the same content that they learned (or that they thought it was appropriate), but instead, they wanted to have their students learn the way that they learned (i.e., process not content).}]

Stephanie:

I'm hoping to actually learn how to tie everything together....We're gonna be learning about the different methods of teaching. That's what I'm hoping to gain from it.

Jessica:

I was thinking I would learn in science methods how I am going to use what I learned, take it to a classroom and fill up the day teaching what I know. What I will actually have to do to get across the things that I need to get across the students without having to tell them these things directly.

Karen:

Learn how to do lesson plans....I'm concerned about day-to-day, what do you do? I mean, how far in advance are you prepared? You know, I have this image, that 10-year veteran teachers have their whole year planned out, but how much can I possibly get done in just this semester to even prepare myself for the 12 weeks of should teaching I have? That's kind of one of the things I'm hoping to get out of methods is that I'll feel ready to go in and student teach.

Bob:

It's the preparation, getting lesson plans together, knowing where you're gonna go with it. I'm hoping to learn all of that....I guess in methods I'm hoping to learn planning and organization, and how to present the material and all of that lesson plan type thing. That's where where we're stuck.

Non- MCTP Teacher Candidate Beliefs and Perceptions. The non-MCTP teacher candidates saw the science methods course as their first opportunity in their undergraduate program to focus on the teaching of science to young learners in an effective and appropriate manner. They expressed interest in learning the strategies to teach science as if they were content independent.

Kelly:

Oh, what I hope to gain in science methods is knowledge of the strategies to teach. This is the first time that they've come up.

Patty:

I would definitely say the different strategies that we need to know. I mean, you know, the more...the more knowledge we have in ways of presenting it ourselves is gonna help, because then I can figure out for myself what's the best way to teach it and then always have something to fall back on if that doesn't work. Because you know, every class is different, and you might have a set of kids one year that just don't seem to get it with this way, and so you just try a different way. So I think the strategies is my biggest hope for the methods classes. ... to get the most out of the kids, and how...how to ask the questions in the right way that...that doesn't turn the kids off.

Anna:

How to come up with questions to ask, because if I was just to give a lesson right now, I would not go too deep with the details to ask how would they get that. So I guess so far I've learned I need more to learn.

Kevin:

Just the different strategies, the different ways of looking at certain topics which are associated with difficulties for children to learn certain topics. How to get around them, how to set them up with different features, and things like that.

Researcher Reflections.

Amy's comments after first interview: [Edit these comments to a summary section that includes exemplar quotes for manuscript]

[{Below is my attempt at summarizing my comments. You may want to re-shape or reduce this section once other reflections are included. Note: I have deleted the original notes and all of the below section is a new version of these notes (with direct quotes from the original notes)}]

Immediately following the first interview, Roth-McDuffie recorded her perception of the interview and initial interpretations of the teacher candidates' responses. These records were kept to ensure that the interpreted meanings gained from participating in a conversation with the participants (and perhaps beyond what one could understand from hearing an audio-tape of the interview) were documented. The below reflections are categorized according to each question asked in the interview (see Appendix [] for the complete interview questions).

1. Preparation to date:

When teacher candidates were asked to reflect on their preparation in their science content courses thus far in the program and the extent to which they feel prepared to teach, Roth-McDuffie perceived that the MCTP teacher candidates "seemed more confident about pedagogical preparation. [They] had the chance to see how math and science professors could bring constructivist ideas into the classroom. A few were unsure as to whether their content preparation was sufficient" (Field notes, September). This uncertainty as to whether or not their content preparation was sufficient did not seem to arise out of a lack of confidence, but rather, it seemed to reflect their ability to metacognitively analyze and question their knowledge base and learning. Roth-McDuffie's reaction to this questioning was that these students had learned enough to realize that there is always more to learn. As evidence of their awareness of what they yet needed to learn, "when asked what they hope to gain from the methods course, they could offer fairly specific ideas" (field notes, September).

In contrast, non-MCTP teacher candidates "seemed quite confident about their content background. They think they have 'covered' everything they would need to teach," with the implication that covering material is sufficient. The non-MCTP teacher candidates did not discuss level of understanding of their previous courses as the MCTP teacher candidates had. Furthermore, they stated that they had no idea as to how they would go about teaching science, and "that was what they hoped to gain from the science methods class" (field notes, September). Again in contrast to the MCTP teacher candidates, when I asked the non-MCTP teacher candidates "if they had any specific ideas regarding what they hope to gain from the methods course, they could only answer in broad terms (e.g., how to teach science)" without offering specific classroom strategies or aspects of teaching and learning that they hoped to learn.

2. Effective learning environment for math: [{Consider skipping this item since not a part of this study. }]

3. Effective learning environment for science:

The MCTP teacher candidates "had fairly clear images in their mind as to how they see an effective learning environment. They could list specific attributes [of effective learning in science such as] forming hypotheses and testing them through actual experiments with a lot of tools, supplies, and equipment available so that children could follow various directions in their thinking" (field notes, September). The non-MCTP teacher candidates used some of the same terms (e.g., "hands-on learning" (field notes, September); however their answers were somewhat superficial in that they did not elaborate on what they means by "hands on learning" or indicate much understanding of how "hands-on learning" could support an effective learning environment.

4. Connections:

Both groups of teacher candidates "seemed to believe that connections [between mathematics and science] were important; however, the MCTP teacher candidates offered concrete examples (often referring back to previous MCTP courses) of how to make mathematics and science connections. Non-MCTP teacher candidates simply indicated that they hoped to learn how to make the connections in the methods course, or they said things [indicating that they saw] math as a tool for science" (field notes, September), again without elaborating on these ideas.

[{Consider cutting items five and six - not much to report here.}]

5. Similarities/differences between math and science disciplines:

For this question, Roth-McDuffie recorded, "No initial patterns come to mind, but I believe it will be worth spending some time analyzing these responses" (field notes, September).

6. Mixed class:

In regard to the teacher candidates feelings about having both groups of teacher candidates in the same methods class, "The MCTP teacher candidates thought about this question, but most concluded that it was not a problem. The non-MCTP teacher candidates looked at me like I was crazy for asking this question, and immediately responded, 'No'" (field notes, September).

Carolyn Parkers' comments [fill-in]

Understanding the Beliefs and Perceptions the Teacher Candidates Held at the Completion of the Science Methods Course

To answer our third research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions upon completion of the science methods course concerning [a spectrum of issues]?") we analyzed the data we collected throughout the semester. This included the end of the semester teacher candidate interview. Once again, what follows are assertions we generated from a careful analysis of the extensive data set we collected. For hueristic purposes, these assertions are presented in the order of the sub-sections of the third research question. Included in each are exemplar comments from the participants that support our assestions.

a. An appropriate science learning environment for elementary students.[fill-in assertion]

[{Consider the following: Instead of offering assertions for each section, as with the previous findings, make a more global statement such as, "Unlike the beliefs and perceptions held by the two groups of teacher cnadidates at the beginning of the semester, at the end of the semseter, fundamental differences did not seem to exist. Instead, the underlying beliefs were quire similar. However, qualitative differences existed in the level in which the two groups of teacher candidates had reflected on and developed these beliefs and on the level of metacognitive analyisis reflected in their expressed perceptions. The MCTP teacher candidates were distinguished by: a greater level of sophistication in their responses; the extent to which they reflected on teaching and learning: and their ability to provide and elaborate on specific, concrete examples."}]

MCTP Teacher Candidates. The MCTP teacher candidates believed that young students should learn science through inquiry characterized by the use of manipulatives, relevant to their lives, cooperative groups, and connected to other subjects.

> Aubrey:
>
> Okay. Providing experiences that the students can use hands-on manipulatives to kind of explore how they think about something and question their own ideas.... Well, for science I think that students should go through the inquiry process where they predict, and test, and then, you know, reflect and stuff at the end.
>
> Bob:
>
> It needs to be applicable. I mean, they should be able to see how it works in the world around them. I mean, whatever problems you pose or whatever, if you can make them real, something that they might experience or see someone else experience close by or just make it as realistic as possible.
>
> Karen:
>
> It could connect to other subjects. It makes it more authentic I guess.... I think that it's important not to just, you know, find your right answer or the wrong answer, maybe find out how it's applicable, or, you know, how it fits into their lives.
>
> (Interview, December)
>
> JESSICA:
>
> Okay.Well, hands-on, group work, teacher as facilitator and learning.
>
> JENNIFER:

Hands-on, minds on.

JESSICA:

Hands-on, minds on, yes.... in science I don't feel that as a science teacher I would need to know all the answers. I don't think that that's an important thing because nobody really knows all the answers in science, and they really aren't answers, they're just theories anyway that can be proven wrong. (Interview, December)

Non-MCTP Teacher Candidates. The non-MCTP teacher candidates believed that young students should learn science in a hands-on manner in which the teacher played a prominent role as a demonstrator of activities.

PATTI:

Hands-on, doing an experiment or doing a demonstration with manipulatives to show, especially with the lower elementary, showing them, actually physically doing it so they understand before they work independently. Not just saying, "Okay. This is what you're gonna do, do it" which is what sometimes happens in the upper elementary or middle school, especially in science. They tend to give them a sheet and say, "Okay. Do this." And sometimes they just...they don't understand it I think. Showing them, going through it with them first and say, "Okay. This is what's gonna happen or...." Of course, some of the experiments, you do you want it to be a surprise to them, so I guess you wouldn't want to go through the whole thing, but maybe go along with them. I don't know. Maybe that's holding their hand too much.

ANNA:

I thinking, like, the hands-on things that that they actively engage the student in actually doing.

KELLY:

Hands on, minds on.

b. Extent to which their science methods professor modeled good teaching of

science. [fill-in]

MCTP Teacher Candidates. The MCTP teacher candidates identified their MCTP science methods professor as modeling good teaching by the use of small cooperative groups, of engaging student-centered activities, of demonstrating various instructional strategies (including making connections between mathematics and science), of an emphasis placed on questioning and discussion, and a concern for creating a classroom enviroment characterized by respect for all. His focus on conducting experiments and discussing personal constructions rather than on memorization of facts were perceived as in alignment with the instruction they experienced in their MCTP science content classes.

Bob:

I'm thinking of one, using peer--small groups--peers, and we did a lot of that in his class, when we did our, you know, lesson plans and then our peers would evaluate it, and that was really good.

Aubrey:

And also, like, the simulation type lessons--the ear and the pencil. You know, there were a lot of things that truly we could transfer into our classes and use and have, you know, confidence in how that's going to play out. I would also say the investigation, the questioning, not being focused on the answer, and that maybe there are many answers to one question.

(Interview, December)

STEPHANIE:

Like modes of learning--we did a lot of experiments. We watched demonstrations, we saw videos, we discussed a lot things.

JESSICA:

He has a high level of respect for everyone, and he maintains a personal relationship and personal notes with everybody, and everybody's opinion or ideas are valued, and that would be effective. Nobody is ever wrong in his class, and I think he calls on a variety of people for answers; he won't key in on a couple of people and ignore anyone. Everybody gets a chance to speak up in his class, which was different than our other classes.... I mean, people who never talked in any classes talked in science [methods].... He's never negative. Everything you say he's very encouraging towards it . The environment, the atmosphere is just like him-- friendly and approachable.

STEPHANIE:

That's definitely something I'd want to do. But whatever it is that he does, like, it makes us all feel very respected, and it makes me enjoy coming to class, and enjoy doing whatever we're doing not matter what it is.

STEPHANIE:

In my physics class, the focus was obviously more the content, and we were talking about heat and temperature. We just explored that for a really long time, but in science methods we touched on a lot of different things. We talked about how, overall, what teaching methods you would use, and how that was appropriate.... [The MCTP science content classes] and the science methods class, those were the same mainly--conduct experiments, and discuss things, like that, talk about what our viewpoints were and not just what the scientists say....Dr. McGinnis, he challenged me.

Non-MCTP Teacher Candidates. The non-MCTP teacher candidates identified their science methods professor as modeling good teaching by making class engaging through the use of activities and demonstrations in which he made them predict outcomes.

KELLY:

We did incredible activities, yeah. He also did demonstrations.

PATTI:

As he was doing demonstrations, he would, you know, have us think, "What's gonna happen next?" So we did a lot or prediction. It was fun.

c. Extent to which they observed their science methods professor making connections to mathematics in his teaching. [fill-in]

MCTP Teacher Candidates. The MCTP teacher candidates identified their science methods professor making connections between science and mathematics throughout the semester. They recognized that specific activities (including the MCTP module) were used by the professor to achieve that goal. They also identified the complete weekly lesson on making connections between science and other subjects as supporting this innovation. It was also recognized that he encouraged them to make connections with mathematics in all their class assignments.

KAREN:

Well, with the ear lesson, that was kind of, it went hand and hand--math and science--and then he made connections to language arts with the...the (Oh, I can't think of it.)...the bus, the "Magic School Bus" book and, then the Science, Technology, and Society topic. ...We did the investigation with the ear. Oh, with our lessons we prepared in science methods we were encouraged to integrate mathematics. I now think that in so many aspects of science you are using math to either solve the problem or analyze the data or, you know, somehow relate it.

Aubrey:

Well, he had one whole class sesson on integrated methods.

JESSICA:

In the beginning of science methods, he gave us the bouncing the ball lesson. We did graphs.... Our Science Investigation, my whole science investigation was math. ..I would think that there was more integration of mathematics in science methods than was evident in the science in math methods.

STEPHANIE:

For Science Investigation I was permitted to integrate mathematics. I did area and circumference of a pizza.

Non-MCTP Teacher Candidates. The non-MCTP teacher candidates recognized that their science methods professor sought to make connections between mathematics and science. They identified a few classroom activities which accomplished this innovation, including the MCTP module.

PATTI:

To what extent did he seek to make connections between science and mathematics ? I would say, like, all the time. For example, the bouncing balls where we had to count how many bounces from different heights. We made graphs. And he even asked how would we tie in the science activities he taught us with math or how could...if this was a math class, how could we tie it to a science? For example, when we talked about gravity.

KELLY:

That last ear thing we did, the ratios.

d. The rationale for and intent to make connections between science and mathematics in elementary teaching. [fill-in]

MCTP Teacher Candidates. The MCTP teacher candidates believed that the rationale for making connections between mathematics and science was to more accurately portray a holistic vision of knowledge. Through this portrayal of the world, a deeper undertanding was possible. They expressed a commitment to extensively make connections between mathematics and science in their practices. They believed, however, that the two displines should only be connected when it was natural, or appropriate, in the context of a topic under study. They believed that mathematics could be connected to science more frequently, and appropriately, than science to mathematics.

Bob:

That's the way our world is. Science and mathematics aren't separate. It should be balanced and that they should be dependent on each other if it's possible. It's hard to do, but they really should be dependent, so you couldn't really do one without the other, or it would make it difficult to do one without the other.

JESSICA:

We're always collecting data in science. I mean, that's all we...and then you're always having to graph it. Math is, like, a tool that you use in science, but science is not a tool that you use in math. Right? Do you know what I mean?

Karen:

Well, I think that you can...you can get a better understanding of...of the different topics and subjects if you can, you know, relate them or analyze them in different ways and show how they relate or what their meaning is to other subjects.

Aubrey:

And it kind of gives you, like, a well-rounded look at things, not from just one perspective or another, more well rounded. It should flow. It should kinda be, like, a subtle integration. I wouldn't say, "Okay. Here's the science part, now this kind of has something to do with it. Let's do some math." We had to do this unit for our reading methods class, and she wanted us to integrate, and she said, "Every lesson has to be integrated." And after eight or nine of them, you know, we were gettin' to the end of the wire. We were just forcing the stuff....So I think it has to kind of really flow and the science and mathematics have to be a real part of each other and not just forced. I think you should always try to because it just makes it that more meaningful, but if you can't, don't force it, you know. That might just turn students off. [In my future teaching] I think I will start off, maybe using some of the examples that we've been given in our classes, the kinds of lessons that they done, and then possibly moving, you know, more into it as I get more comfortable with it.

KAREN: Well, with the flow I think that making connnections between science and mathematics needs to be meaningful...for it to be true integration, for it to be meaningful, it needs to be more into the content or the processes of that subject. I definitely like to make connections in my future teaching, but it's not as easy as it sounds, and I think it'll take a lot of more practice. (Interview, December)

STEPHANIE:

A lot of things in science you really need math. I mean, you can always integrate math. I mean, you could talk about how light reflects on a mirror, and if you've gotten more complicated you could measure angles of reflection and things like that, naturally. However, I was thinking that I did a lesson on cells and I don't really see how math was involved in that.... I also think that the kids that already understand mathematics are gonna do good and do wonderful when all they do math work. The kids that don't understand it are just gonna get further, and further, and further behind, and they need some sort of science investigation type understanding in order to get the concept.

JENNIFER:

For me, I would prefer to integrate science and mathematics naturally. I would put the connections in an introduction to a lesson. I mean, I do think that the students should be able to decipher between mathematics and science.

JESSICA:

I think that I would introduce it as more of an activity type of thing, more of, like, a science activity that maybe introduce math because I know that's what I'm doing next week in the schools. It's kind of like a science experiment, but it integrates math, and it takes using a graph. And then once they have collected all their data and they have real-life stuff, that's when they start getting in the mathematics aspect of it.

Non-MCTP Teacher Candidates. The Non-MCTP teacher candidates believed that science and mathematics were connected by requiring the same sort of thinking processes. While they expressed support for making connections between mathematics and science, they were particularly hesitant to make what they perceived as inappropriate curricular connections. Examples provided by them on making connections between the disciplines portrayed mathematics as a tool in science.

KELLY:

Mathematics and science use the same kind of thinking, I mean, use the same kind of thinking processes. However, they should only be integrated in those types of lessons where they reinforce each other.

ANNA:

I think not all science lessons are gonna have some math in them, so if a teacher just throws the math in there, then it wouldn't be appropriate in all cases. This semester, I did a lesson in my field placement that connected mathematics and science. My cooperating teacher wanted me to think of a lesson which connects the two, the math and the science. So my lesson was on, taking the temperature during different times of the day to see when it would be hottest, and then they were supposed to look at the thermometer and know the difference in temperature, temperature trends. Like when was it the hottest.... But they do need some subtraction skills in order to do that, so...so my teacher wanted me to do it after she taught the subtraction lesson.

Reflections on Teaching Practice By the Co-Reseacher.

At the end of the semester, Roth-McDuffie recorded her thoughts and perceptions about the teaching and learning in the course and the students' reactions to the course. In reflecting on the semester, Roth-McDuffie referred to her field notes to make some more global observations. First, Roth-McDuffie considered McGinnis' efforts to achieve his goal of making connections between mathematics and science in this science methods course. Roth-McDuffie wrote,

> "Throughout the semester, I observed several instances of Dr. McGinnis making a deliberate effort to make connections between mathematics and science in his class. In planning his lessons, he thought about the mathematics involved in the lesson, [especially the mathematics] that might be taken for granted by a person with his level of expertise [as a scientist] (Field notes, 10/8/97). In addition, he directly discussed these connections with the students; rather than leaving it to the students to realize (or perhaps not realize) that connections were being made (Observation, 10/27/97). (Field notes, December)

The evidence seemed to indicate that McGinnis was achieving the goal of helping the teacher candidates to see the connections between mathematics and science. In interviewing the teacher candidates, Roth-McDuffie perceived that they all had developed a greater sense of the relationship between mathematics and science during the semester. Roth-McDuffie recorded the following observations,

> In teaching their own students, the teacher candidates [desire to] strive to make "natural connections" (Interview, Jessica, 12/96) between mathematics and science without their students having to think about whether they are studying mathematics or science. Moreover, in preparing to teach this way, the teacher candidates seemed to benefit from opportunities to be aware of and to understand Dr. McGinnis's efforts to make connections. (field notes, December)

Roth-McDuffie also reflected on the extent to which others might achieve what McGinnis had achieved in his classroom, helping teacher candidates to understand the connections between mathematics and science (both in terms of content and pedagogy). Below are her reflections on this challenge:

> While we may endeavor to make "seamless" (a word used [by faculty] in the MCTP working sessions) connections between mathematics and science for the MCTP teacher candidates, the connections cannot necessarily be made without concerted effort on the part of the professors. Earlier research conducted by McGinnis and Watanabe (1996) showed that MCTP science professors tend to view mathematics only in term of how it serves their own discipline. McGinnis and Watanabe (1996) found that scientists tend to view mathematics as a tool for doing science. However, to achieve integration in teaching and to help teacher candidates see commonalties and connections between the disciplines of mathematics and science, science professors need to step outside of their own discipline and examine how one from mathematics might view the problem. This action requires thought and planning beyond saying, "I am going to have students graph the data to bring in some mathematics." As stated earlier, I observed this type of thought and planning in Dr. McGinnis's science methods course. However, based on these observations, I caution anyone who is intending to attempt an integrated approach to a science methods course. Such a challenge should only be attempted when it can be made a priority (for the semester or even for a particular lesson). Without careful thought, the danger is that the connection made is only superficial and may result in reinforcing notions of mathematics only as a tool. In this study, the ideas that the MCTP students developed of mathematics and science being inextricably linked by common processes and approaches came about by a carefully conducted and highly focussed teaching innovation. (field notes, December)

Implications

In regard to McGinnis' goal of helping students understand the connections between mathematics and science, while he was quite successful in achieving this goal, we need to consider Steen's (1994) recommendations. While McGinnis' course did not promote the idea of mathematics only as a tool for doing science, the teacher candidates did not seem to view mathematics as more than this when discussing the *discipline* of mathematics. Referring back to Steen's notion that the two disciplines are "fundamentally different enterprises" (Steen, 1994, p.9), this finding serves as evidence that by viewing the disciplines from a connected perspective, a limited view of mathematics emerges. However, when discussing the *processes* of science and mathematics, the students perceived many commonalities (e.g., investigation, problem solving, etc.) and demonstrated a more developed understanding of these processes in each discipline. Again this finding is consistent with Steen's (1994) recommendations that in integrating mathematics and science we should focus on the methodologies of the disciplines (i.e., focus on the commonalities of *how* we do mathematics and science, rather than *what* is common between mathematics and science).

When comparing the two groups of teacher candidates, at the beginning of the semester, we see fairly stark contrasts in their beliefs and perceptions about their preparedness to teach, their vision of an effective learning environment, and their understanding of connections between mathematics and science. Quite predictably, the MCTP teacher candidates had beliefs and perceptions that were consistent with their experiences in the MCTP program, while the non-MCTP candidate relied on more traditional, lecture-based preparation.

However, at the end of the semester, after sharing the common experience of being in a science methods course which was based on MCTP goals, both groups expressed similar ideas on the above issues. The difference at the end of the semester was not in the basic terminology used or the fundamental ideas expressed, but rather, in the depth and sophistication of understanding conveyed in the responses. Consistently, the MCTP teacher candidates offered responses that were more developed in the way they explained their ideas, and they provided more specific examples of their thinking as compared to the non-MCTP candidates. With a background of more experiences in this type of learning environment and with more opportunities to reflect on their thinking and learning (and the implications for their own teaching), the MCTP students articulated a well developed philosophy of teaching science. Whereas, the non-MCTP students just had begun this process.

This finding indicates that this one-semester course was enough to affect the beliefs and perceptions of both groups of teacher candidates. However, the impact was not enough to allow the non-MCTP teacher candidates to "catch up" to the MCTP teacher candidates in developing a carefully thought-out philosophy of teaching and learning. The question remains as to whether either group has been affected enough to bring about reform-based teaching in their future classroom practices.

Table

Sources of Data

Data Source Participants

Interviews:

a.) Pre-& Post-Semi-Structured Interviews 6 MCTP Teacher Candidates;

(audio-taped and transcribed) 3 Non-MCTP Teacher Candidates

Professor of Science Methods Class

b.) Mid-Semester Group Interview 9 MCTP Teacher Candidates;

(video-taped) Science Methods Professor,

Mathematics Methods Professor, and

Graduate Research Assistant

Observations: Regular Observations of the Science

Methods Class, focusing on the

(video-taped) MCTP Teacher Candidates

Journals: 9 MCTP Teacher Candidates;

Professor of Science Methods Class

Student Work: 6 MCTP Teacher Candidates;

[written assignments and poster display] 3 Non-MCTP Teacher Candidates

Field Notes: Professor of Science Methods Class

and Graduate Research Assistant

Content Diagnostic All Teacher Candidates in the Science

Methods Class

Other Artifacts: Course Syllabus, Class Handouts

Table

Mann-Whitney U Analysis of GALT Scores

Groups Compared	Cases	Mean Rank	U Value	2-Tailed P
1.) MCTP and	7[1]	20.43	46.0	0.08
The Other Classmates	23	14.00		
2.) MCTP and	7	8.43	18.0	0.40
Science Concentration	7	6.57		
3.) MCTP and	7	6.93	7.5	0.21
Math Concentration	4	4.38		
4.) MCTP and	7	12.43	32.0	0.27
Science and Math Concentrations	13	9.46		

Note: At the end of the semester, seven the teacher candidates were identified as MCTP teacher candidates as determined by their meeting all requirements to enter student teaching as an MCTP teacher candidate. Thus, we determined that these seven teacher candidates comprised our group of MCTP teacher candidates for research purposes as well. One of the seven was not included in the semi-structured interviews during the semester since she was accepted as an MCTP teacher candidate during the middle of the study semester.

TABLE

Mann-Whitney U Analysis of Science Diagnostic Instrument Scores

Total Score

Groups Compared Cases Mean Rank U Value 2-Tailed P

1.) MCTP and 7 20.07 48.5.0 0.11

The Other Classmates 23 14.11

2.) MCTP and 7 7.64 23.5 0.90

Science Concentration 7 7.36

3.) MCTP and 7 7.29 5.0 0.09

Math Concentration 4 3.75

Physical Science

Groups Compared Cases Mean Rank U Value 2-Tailed P

1.) MCTP and 7 18.79 57.5 0.26

The Other Classmates 23 14.50

2.) MCTP and 7 7.71 23.0 0.85

Science Concentration 7 7.29

3.) MCTP and 7 6.93 7.5 0.22

Math Concentration 4 4.38

Life Science

Groups Compared Cases Mean Rank U Value 2-Tailed P

1.) MCTP and 7 18.14 62.0 0.36

The Other Classmates 23 14.70

2.) MCTP and 7 7.07 21.5 0.70

Science Concentration 7 7.93

3.) MCTP and 7 7.43 4.0 0.06

Math Concentration 4 3.50

Earth and Space Science

Groups Compared Cases Mean Rank U Value 2-Tailed P

1.) MCTP and 7 20.43 46.0 0.09

The Other Classmates 23 14.00

2.) MCTP and 7 7.14 22.0 0.75

Science Concentration 7 7.86

3.) MCTP and 7 7.29 5.0 0.09

Math Concentration 4 3.75

Table 4

Course Evaluation of the Professor's Elementary Science Methods Class By Semester/Year

-

S96 F96 S97 [a]F97

1. Number enrolled in class/respondents 25/22 26/26 21/20 30/30

2. Strong desire to take course 3.3 3.6 3.6 4.1

3. Improved Attitude toward Field 4.5 4.5 4.9 4.7

4. Related Material to Real Life Situations 4.8 4.9 5.0 4.9

5. Introduced Stimulating Ideas 4.5 4.6 5.0 4.8

6. Would Like Instructor Again 4.8 4.6 4.9 4.8

Note [a] The action research study semester. [b]The range for all responses is 1-5, with 5 the most positive.

Figure One. Program Overview Of The MCTP.

Appendix

Teacher Candidates Interview Protocols

Beginning of Semester

1. Now that you have completed your content area preparation in science, to what extent do you feel prepared to teach this subject area?

MCTP teacher candidates only: To what extent did your MCTP content classes prepare you to teach this subject?

2. What do you hope to gain from your methods course that you have not yet learned in your program so far?

3. What is you image of an effective learning environment for science instruction for elementary and middle level students?

4. Do you believe it is important to make connections between mathematics and science in teaching and learning at the elementary and middle level? Why or why not?

5. What similarities, if any, do you see between the structure of mathematics and science? What differences?

6. What problems, if any, do you foresee by being in a mathematics methods class and a science methods class containing both non-MCTP and MCTP teacher candidates?

End of Semester

1. How would you define best practices in teaching science to upper elementary/middle level students? Probe: What strategies/methods/approaches?

2. This semester, what attempts at best practices did you see your science methods professor modeling in science methods?

3. In your science methods class, to what extent did you see your science professor attempting to make connections to mathematics? Probe: Please give examples. Please consider both content and processes.

4. What is your understanding of the reasons given to make connections between mathematics and science? Probe: If you were to observe an attempt to make connections between mathematics and science, how would you evaluate it? What would you look for? Are there any times it is not appropriate to make connections?

5. Do you see a role for making connections between mathematics and science in your future teaching? Please give examples.

6. Did you encounter any problems by being in a science methods class containing both non-MCTP and MCTP teacher candidates?

Appendix

Professor Interview Protocol

Beginning of Semester

1. Do you plan to highlight connections between mathematics and science in your MCTP course? If so, can you give an example? Are you giving any assignments to the teacher candidates requiring them to conduct a lesson or activity with children that involves making connections between math and science?

2. Do you plan to utilize technology (e.g., calculators, computers, e-mail) in your MCTP course? If so, can you give an example? Are you giving any assignments to the teacher candidates requiring them to conduct a lesson or activity with children that involves using technology?

3. Do you plan to encourage your students to reflect on changes in their ideas about topics in your class? If so, can you give an example? Are you giving any assignments to the teacher candidates requiring them to conduct a lesson or activity with children that involves reflecting on changes in their

ideas?

4. What kinds of assessment techniques do you plan to use in your MCTP class? Why?

5. What is your role in the teacher education process?

6. It has been said that teachers teach in the way they were taught. If you were to visit your MCTP students classes in the future, what elements would you hope to see in their teaching that you plan to model this semester?

7. Are your expectations of MCTP students different from non-MCTP students? Do you expect any difference in the MCTP students subject matter competence? Please explain any expected differences.

8. How has your involvement with MCTP affected your plans for teaching the MCTP methods course? Do you plan to teach the MCTP methods course differently from methods courses you have taught in the past? How? Why?

9. What problems, if any, do you foresee by teaching a methods class of both MCTP- and non-MCTP- prepared students? Are you planning separate/additional assignments for the MCTP students?

10. Please add any comments or thoughts you might have about the MCTP methods course, your teaching, or the MCTP students that have not been addressed above.

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