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ABSTRACT

This study questioned whether there is a difference between Maryland Collaborative for Teacher Preparation (MCTP) teacher candidates and non-MCTP teacher candidates in the science content knowledge, beliefs, and perceptions they bring to their science classes, and in whether they complete the science methods course in their teacher education program. The study evaluated student teachers according to content preparedness to teach elementary students, their vision of an appropriate science learning environment for elementary students, and the rationale for and intent to make connections between science and mathematics in elementary education. (Contains 11 references.) (YDS)

MAKING CONNECTIONS BETWEEN SCIENCE AND MATHEMATICS IN A SCIENCE METHODS COURSE: ASSERTIONS AND REFLECTIONS OF THE PARTICIPANTS

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Overview and Rationale

This study interprets the efforts made by one elementary science methods professor to make connections between mathematics and science in an elementary science methods course. There is currently considerable interest in preparing science teachers to make connections with mathematics; however, there is a dearth of empirical studies that systematically study the implementation of this teaching innovation. The focus of this report is not to document the innovation in teaching practice but to present researcher assertions and reflections concerning the innovation. Participants in this study include the professor and his coresearcher and the thirty teacher candidates in the course. Special focus is on six teacher candidates participating in a special National Science Foundation funded undergraduate teacher preparation program (the Maryland Collaborative for Teacher Preparation, MCTP) and on a comparison non-MCTP group consisting of three elementary education majors with concentrations in mathematics or science.

Context of the Study

The MCTP is a NSF funded statewide undergraduate program for teacher candidates who plan to become specialist mathematics and science upper elementary or middle level teachers. The goal of the MCTP is to promote the development of teachers who are confident teaching mathematics and science, 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). The program has sought to: (a) introduce future teachers to standards-based models of mathematics and science instruction; (b) provide courses and field experiences that integrate mathematics and science; (c) provide internships that involve genuine research activities; (d) develop the participants' ability to use computers as standard tools for research and problem solving, as well as for imaginative classroom instruction (through training on how to incorporate calculators, microcomputer-based laboratories, and the Internet into their instructional practices); (e) prepare prospective teachers to deal effectively with the diversity of students in public schools today; (f) provide graduates with placement assistance and sustained support during the critical first years of their teaching careers. This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities. In practice, the MCTP undergraduate classes are taught by faculty in mathematics, science, and education, who strive to diminish faculty

lecture while emphasizing student-based problem-solving in cross-disciplinary mathematical and scientific applications.

Theoretical Assumption and Research Methodological Approaches

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). To test this assumption, an empirical study using an action research approach (Collins, 1995) with an N of one (a case study) was designed. A common focus of action research is to promote a self-reflective analysis that can improve teaching practice and our understanding of practices (O'Hair, 1995). This study also takes a symbolic interaction theoretical stance (Blumer, 1969; Denzin, 1978). Symbolic interactionism makes the assumption that meanings are constructed by humans through interaction. A central premise is that inquiry must be grounded in the empirical environment under study.

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?

Data Collection Strategies

Observations

A coresearcher regularly observed and videotaped the science methods class.

Interviews

A coresearcher conducted semi-structured interviews (taped and transcribed) with the six MCTP teacher candidates and three non-MCTP teacher candidates as a comparison group. The interviews were conducted at the beginning and the end of the semester in groups of two or three. Each of the interviews lasted approximately 30 minutes. In addition to the semi-structured interviews, the professor of the class conducted an open-ended, videotaped group discussion with the MCTP teacher candidates in the science methods class. The group discussion focused on ideas about integrating mathematics and science in teaching and learning.

Journals

Both the professor and the teacher candidates in the class keep journals in which they regularly reflected on the pedagogy of the science methods class.

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 75-item "Science Content Diagnostic" was crafted by the researchers from existing items in the literature (Gega, 1986) that aligned with recommendations made in the *National Science Education Standards* (National Research Council, 1996).

Findings

Question 1

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. 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 1 (Note: a higher rank signifies a better score.)

Table 1
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	11	9.46		
Concentrations				

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.

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: (a) total score; (b) physical science score; (c) life science score; (d) 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.

Table 2

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		

(Table 2 continued, next page)

3.) MCTP and	7	6.93	7.5	0.22
Math Concentration	4	4.38		

Life Science

Groups Compared				
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		

The MCTP teacher candidates' total scores were significantly higher than the mathematics concentration teacher candidates' scores ($p = 0.09$). 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 ($p = 0.06$) and the earth and space sciences ($p = 0.09$) 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 ($p = 0.09$). 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.

Question 2

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 comparison 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 assertions.

Content Preparedness to Teach Elementary Students

The MCTP teacher candidates were distinguished from the other teacher candidates 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.

Mary:
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)

Mark:
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.

Margaret:
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)

Joseph:
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)

Molly:
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)

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 contrast 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 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.

Laura:

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)

Mark:

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)

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 believed 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.

Lisa:

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)

Molly:
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)

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.

> Susan:
> 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.(Interview, September)

> Katie:
> I think that one of the reasons Susan 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. (Interview, September)

> Mary:
> 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. (Interview, September)

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.

Margaret:
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. (Interview, September)

Joseph:
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]. (Interview, September)

Molly:
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. (Interview, September)

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 that they believed was inappropriate for young learners. They saw the science methods as their first opportunity 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 the opportunity to develop the strategies and knowledge necessary to create learning opportunities and environments similar to what they previously experienced in their MCTP content classes

> Susan:
> 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. (Interview, September)

Katie:
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. (Interview, September)

Mark:
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 we're stuck. (Interview, September)

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.

Molly:
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. (Interview, September)

Lisa:
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. (Interview, September)

Joseph:
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. (Interview, September)

Question 3

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 heuristic 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 assertions.

An Appropriate Science Learning Environment for Elementary Students

The MCTP teacher candidates thought young learners should learn science through inquiry characterized by being connected to other subjects and requiring active student participation. The non-MCTP teacher candidates expressed a vision of an appropriate learning environment for young students characterized as being teacher-centered with engaging hands-on activities.

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.

Mary:
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. (Interview, December)

Laura:
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)

Katie:
Okay. Well, hands-on, group work, teacher as facilitator and learning. (Interview, December)

Blanche:
Hands-on, minds on. (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.

Lisa:
I thinking, like, the hands-on things that that they actively engage the student in actually doing. (Interview, December)

Molly:
Hands on, minds on. (Interview, December)

Extent to Which Their Science Methods Professor Modeled Good Teaching Of Science

The MCTP teacher candidates were able to describe the teaching of their methods professor in a rich manner, which identified many teaching practices that they believed were

effective. These practices included the use of small cooperative learning groups, student-centered activities, making connections between science and mathematics, and an emphasis on classroom discourse. His use of experimentation and on the personal construction of knowledge rather than on the memorization of facts were perceived as in alignment with the instruction they experienced in their MCTP science content classes. In contrast, the non-MCTP teacher candidates evaluated the science methods professor as modeling good teaching practices such as the use of student-centered activities but were not able to link his practices with previous science teachers they had experienced.

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 environment 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.

> Mark:
> 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. (Interview, December)

Mary:
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)

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.

Molly:
We did incredible activities, yeah. He also did demonstrations. (Interview, December)

Margaret:
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. (Interview, December)

Extent to Which They Observed Their Science Methods Professor Making Connections to Mathematics in his Teaching

Both the MCTP teacher candidates and the other teacher candidates readily identified multiple instances in which the science methods professor sought to make connections between science and mathematics. The MCTP teacher candidates were distinguished in the greater number of instances which they identified as fulfilling this curricular innovation.

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.

> Laura:
> 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. (Interview, December)

> Susan:
> For Science Investigation I was permitted to integrate mathematics. I did area and circumference of a pizza. (Interview, December)

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 that accomplished this innovation, including the MCTP module.

> Margaret:
> 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. (Interview, December)

Molly:
That last ear thing we did, the ratios. (Interview, December)

The Rationale For And Intent To Make Connections Between Science And Mathematics In Elementary Teaching

The MCTP teacher candidates were distinguished from the non-MCTP teacher candidates in the advanced manner in which they could articulate a rationale for and intent to make connections between science and mathematics. The MCTP teacher candidates supported the curricular innovation to make connection between science and mathematics whenever it was appropriate in order to more accurately portray a holistic vision of knowledge. The non-MCTP teacher candidates were more wary of making connections between science and mathematics and more likely to portray mathematics as a tool when connections were attempted.

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 understanding was possible. They expressed a commitment to extensively make connections between mathematics and science in their practices. They believed, however, that the two disciplines 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.

Mark:
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. (Interview, December)

Mary:
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. (Interview, December)

Laura: Well, with the flow I think that making connections 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)

Blanche:
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. (Interview, December)

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.

> Molly:
> 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. (Interview, December)

> Lisa:
> 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. (Interview, December)

Researcher Reflections

McGinnis

In my planning for this curricular innovation in teacher preparation, I based much of my thinking on an extensive literature review Roth-McDuffie and I conducted on making

connections between science and mathematics. In particular, two areas were examined: professional associations' call for mathematics and science integration and theoreticians' conceptualization of mathematics and science integration. While I was heartened that professional associations had historically supported the MCTP's program's goal to make connections between mathematics and science in teacher preparation, I found scant intellectual guidance until I read Steen's (1994) theoretical piece. What follows for the reader's inspection is what I constructed Steen was promoting and what I found compatible with my personal notion of curricular connections.

Steen (1994) discusses possible ways to integrate mathematics and science. These methods include: (a) using mathematical methods in science; (b) using science examples and methods in math instruction; (c) teaching math entirely as a part of science; (d) teaching science entirely as a part of mathematics; (e) 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).

Taking Steen's suggestion as my organizational principle, I worked throughout the semester to make connections between science and mathematics by seeking linkages among instructional methodologies. I was pleased that from my observations throughout the semester of my teacher candidates in the course that my efforts were met with their approval. From the analysis of the teacher candidate interview data, I have learned that a one course concerted attempt to make connections between science and mathematics can result in positive outcomes. I also have learned that teacher candidates who come to the science methods with prior experience in learning science in a connected manner with mathematics are better able to conceptualize the innovation and to resist the tendency to portray the use of mathematics in science contexts simply as a tool. I am left, however, with the conviction that this form of innovation requires an extremely high level of planning and commitment on the methods professor's part to lessen the occurrence of teacher candidates constructing inappropriate visions of the use of mathematics in science contexts which may disturb mathematicians and mathematics educators. Therefore, while

recommending continued explorations in this effort to make connections in teacher preparation between science and mathematics, I offer a cautionary note for science teacher educators to proceed in a manner that is informed by the concerns many mathematics (and science) educators hold in this endeavor.

Roth-McDuffie

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, Katie, 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 Watanabe and McGinnis (1996) showed that MCTP science professors tend to view mathematics only in term of how it serves their own discipline. Watanabe and McGinnis (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 more preferable type of thought and planning in Dr. McGinnis's science methods course. However, based on the observations with the teacher candidates in the methods class, 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 focused teaching innovation. (field notes, December)

Parker

A year after the study, Parker (a doctoral level science education student who had two years experience with the MCTP) read a draft of the manuscript and gave the following reaction.

Having had the opportunity to teach in a variety of settings, I understand and have reflected upon the complexity of helping not only younger students, but also teacher candidates make connections between mathematics and science. Given the objectives of the Maryland Collaborative for Teacher Preparation and its attempt to create a seamless fusion of mathematics and science, the statements recorded by the Collaborative students are provocative, but I was not surprised by both the breadth and depth of the group's responses.

The teacher candidates' rationale for and intent to make connections between science and mathematics in elementary teaching is particularly thought provoking. In particular, the following two comments demonstrate to me how the MCTP's future teachers understand the two disciplines as inextricably linked, not as separate entities to be taught within a vacuum.

> Susan:
> 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.
>
> Katie:
> I think that one of the reasons Susan 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.

As a science teacher educated in a large research university, I can reflect and characterize my first few years as teaching to that of the non-MCTP teacher candidates who were described as having not reflected on a rationale for making connections between the disciplines and who thought of math only as a tool for science. I have only recently come to recognize the common processes of the disciplines, a theme that permeates the words of the six students represented by this study.

The MCTP's continuum of education consisting of integrated, interactive content courses, methods courses taught by professors committed to an integrated approach, a unique capstone course supplemented by research internships have been well-represented by the participants comments. They understand the interrelationships between the various components and have integrated the MCTP's approach to present a seamless relationship between the two disciplines. I envy the future young members their classrooms.

Conclusion/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 commonalties (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 commonalties 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.

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