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ABSTRACT

This study identifies some of the questions mathematics educators must address in designing methods courses for graduate students in preservice teacher education programs. The questions emerge from a pilot study of preservice early childhood graduate students' beliefs about the nature of mathematics and science. In a combined mathematics and science methods course, students used each discipline as a backdrop for considering the nature of the other discipline. Three important questions related to mathematics are the following: (a) How can mathematics be better contextualized? (b) How can mathematics be presented as a growing, changing field that, like science, invents new knowledge? (c) How can students learn to ask their own mathematical questions and pursue their own mathematical investigations? (Author/MKR)

Science as Backdrop for Reflecting on Mathematics with Preservice Teachers

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SCIENCE AS BACKDROP FOR REFLECTING ON MATHEMATICS WITH PRESERVICE TEACHERS

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This study identifies some of the questions mathematics educators must address in designing methods courses for preservice graduate students. The questions emerge from a pilot study of preservice early childhood graduate students' beliefs about the nature of mathematics and science. In a combined mathematics and science methods course students used each subject as a backdrop for considering the nature of the other.

Mathematics and science are the focus of much new curriculum and course development in preservice education. Combining these with other subjects is not generally new practice in preservice teacher education programs in early childhood, yet few course instructors have developed purposeful strategies for designing and facilitating learning experiences to deepen preservice students' knowledge and understanding of content as well as methods in both science and mathematics. It is important that preservice teachers at all levels develop a personal understanding of the nature of both mathematics and science in order to represent these disciplines with integrity (Steen, 1991).

Background

While co-teaching a mathematics and science methods class for graduate school preservice teachers in autumn, 1994, the authors were surprised to find what appeared to be deeper resistance to mathematics than to science. Subsequently, we studied those differences and their implications for preservice students' teaching and for ours. In the spring science and mathematics methods course we did not want to teach the subjects separately, nor could we justify complete integration of the two. Because of the dual focus we felt the course provided a rich opportunity for reflection on the nature of mathematics and science.

Graduate students in preservice courses bring with them already-established perspectives on content areas, and their stances toward mathematics and/or science often vary. We set out to understand the range of those perspectives, to characterize them, and to develop some notions of how those perspectives might inform the design and implementation of a methods course that dealt with both mathematics and science. We were also concerned to determine the relative flexibility of those perspectives so that we could think realistically about what is possible in early childhood methods courses combining mathematics and science.

It has long been held that what teachers believe about learning is influenced in substantial ways by experiences long before they begin to teach, and these beliefs may not change without some significant intervention. Cooney suggests (1993) that it is crucial to "develop a way of thinking about how teachers orient themselves to their students, to the mathematics they are teaching and to the way that they see themselves teaching."

These three elements—orientation to students, view of mathematics and science, and their vision of themselves as teachers—underlay the design of our combined mathematics and science methods course for early childhood students.

Orientation to students: We required graduate students to observe and interview children four times to analyze understanding of scientific and mathematical concepts (Harlen, in press). Students also viewed, discussed, and analyzed selected videotapes of children engaged in mathematics or science.

View of mathematics and science: Central to the course were scientific and mathematical investigations designed to enhance graduate students' content knowledge and their views of how science and mathematics are conducted (Shulman, 1990). We believe our students must themselves participate in such investigations, with all the false starts, uneven results, and excitement of real mathematics and science.

Vision of self as teacher: The learning environment in the course emphasized discourse, question-asking, reflection, and listening.

The Study

In this study, we characterize preservice teachers' beliefs and sketch some apparent changes in beliefs about mathematics and science. The questions that guided our research were:

- How do preservice students understand the nature of mathematics and science and the connection between mathematics and science?
- How do graduate students orient themselves to young children's understanding?
- How do they see themselves as teachers of young children?

For this presentation, we emphasize the first question: the nature of mathematics and science as fields of knowledge. In this report we will focus in depth on three graduate students (a reasonably adequate representative sample of the eleven-woman class). These three were interviewed following the first class session and again following the last class session by an interviewer who did not teach the course. Interviews and writing were primary data sources. Written materials included mathematics and science autobiographies, course assignments, responses to course readings, reflections on their own learning, and structured reflections on science and mathematics.

Profiles

These short profiles present three students' contrasting stances toward science and mathematics. Each of the three is a woman between 24 and 34; each intends to teach children who range in age from 3 to 9 years. Their positions and beliefs are different, yet some of the themes are troubling to us. After the profiles are presented, we discuss some of those questions.

Profile #1: Diane: I was always in that "other group"

> My math and science education from Nursery School through Third Grade is very faint to me with a few exceptions. My first recollections begin in Fourth Grade when I remember being in the "other" math group, which continued right through High School.

When first interviewed, Diane sees mathematics as quite different from science. She describes science as philosophical—although there may be established theories, those are debatable and allow choices of what to believe. In contrast, mathematics is quite different.

> I see math as concrete because I see math as adding and subtracting and multiplying and there being one definite answer; whereas in science, theories are always being re-tested and re-tested and sometimes re-evaluated and new answers.

Diane feels mathematics is more bounded; it is computational, focused on one right answer. Mathematics exists as an external body of knowledge, necessary to master by hard work, because "those basic skills will be needed to survive."

Diane's views of science are set in the context of the natural world. In elementary school she stored "precious [rock] samples in my very own egg carton" in fourth grade, and her sixth grade teacher's enthusiasm about birds dominates her memory of that year.

Finding contexts for mathematics is more difficult; Diane's context for mathematics is computational—balancing checkbooks and cooking—"those sort of basic, everyday, need-to-know, help you get through the day kinds of things". Other aspects of mathematics she labels "abstract".

Diane's view of learning seems to focus on hard work, discipline, and control. The teacher needs to be in charge so that knowledge can be passed on to the children. During the course this appears to soften somewhat, as this reflection hints:

> Obviously, the basic mathematics—addition, subtraction, multiplication, and division—those are obviously things that can be applied to everyday life. But I think sort of the process of discovering and of understanding them and asking questions and getting wrong answers—and this goes for both math and science—testing them out and learning through mistakes and trying and trying again until you figure it out really to understand it. I think those are really important skills that come from learning math and science, that can be applied to lots of other things.

Profile #2: Sophia: "Counting spots on lions, tigers, and giraffes"

> I remember as a kid just sitting there and going through the multiplication tables across the classroom or doing "one plus one is two" and I mean *without* music behind it. Not having to do with art. It was really boring. It was the class time that I dreaded most. It was cold. I mean, there's *nothing* creative about it, nothing fun about it. Tedious work.

This somewhat dismal view of her childhood mathematics is Sophia's first statement about the nature of mathematics. She goes on to say,

> You don't study math, you just get at different answers ... There's not different ways to go about it. Like [in] a science project you can go about different ways to get to the same answer. You can answer your own different questions. But in math, it seems like there's one correct way to do it and that's it.

For Sophia, science asks questions, that embraces curiosity and creativity, "the study of ways, things, life, people, bugs." In her first interview, Sophia sees mathematics as separated from the world:

> But I think a lot of students end up learning by rote and end up just hating math because of that. Because there's no actual tie-in to everyday life. I mean, there's nothing fun about it.

This separation between mathematics and life is not evident at the end of the course, when she says, "all real things have to do with math and science" and talks about the mathematical opportunities she finds in her garden. Newly aware of connections among science, math, and art, she thinks about how observations made in her garden and her art work include mathematics—proportions of paint colors, percent yield from seeds planted—and says, "Math is also really intricately involved with science...it's not just balancing a checkbook".

Sophia appropriates mathematical ideas *because* she can think of them in familiar artistic contexts. There is evidence that in her own classroom she will bring mathematics and science to her students in informal, everyday contexts,

> Just so it makes sense. And it's not this weird idea out there that you have to memorize. But it actually does make sense. And it has to do with everyday life.

Profile #3: Sandi: No, no, no! Give me the answer, because I have to have the answer!!!

Until the age of eight Sandi describes herself as fascinated by insects and intrigued by life in the woods on her way to school. She says she always wanted to find out more. Sandi considers science a process of investigation:

> Science is finding out about the things around the world. It's also increasing knowledge. It's finding out why something works the way it works. Or does something the way it does.

She describes mathematics as other course members do:

> Mathematics to me would be all about numbers. Givens. About something that is arguable. Some memorization. Hard. Difficult. Can I say boring?

During the semester, though, there is evidence that she wonders about her view of mathematics. Sandi seems to wrestle with her own ideas. It is as if she argues with herself all semester about mathematics. It is in the context of its relationship to science that she questions whether mathematics can really be that cut and dried. She explains that during the course,

> I started to think of math more, instead of automatically writing down a problem. I could sort of round it off in my head and not worry that it needs to be exact.

Later she mentions what she wants children to gain from doing mathematics:

> Seeing relationships, I guess. Like the example with the baby chick and the Unifix cubes. Seeing how two different things can weigh the same. Or figuring out that a certain number of cubes would increase with the weight increase of a baby chick. It's like that relationship and understanding it as a whole thing.

She seems to move away from a static view of mathematics as finding the right answer:

> I started to think about the whole learning process. ... There's no challenge in the answer. There's challenge in the investigations and the inquiries into how things happen or why.

Puzzling out what she sees as a contradiction—her belief that science is never-ending yet mathematics is limited—Sandi takes Fibonacci and his number sequence as evidence that new knowledge may be possible in mathematics:

> For me, science is never ending. There's always something else to learn. For math it seems like once you know all there is to know about math, that that's it. I mean, even though there are other things like the snail and [the Fibonacci series]...How things have a sort of a pattern. And he came up with that and saw that in things. But then again I guess that's not—you could always maybe find something new. Or a new pattern. Or new sets of numbers that might equal something that people may have never even thought of before, or seen.

Troubling questions

As we focused closely on each of the graduate students' views of the nature of mathematics and science, their views about children, and their views about teaching and learning, the patterns we noticed have left us with questions.

1) *What mathematical contexts are most appropriate?*

Although students talked about science they placed their talk in familiar contexts, their comments about mathematics were almost entirely context-free. In the few instances where students set mathematics into contexts associated with their own lives, it seemed to have more meaning. This was illustrated as Sophia began to see mathematics in the art and gardening she loved.

How do we help our graduate students begin to look at their world with a mathematical eye? How can we contextualize the mathematics to support students' developing awareness of a mathematical perspective?

2) *How can we present mathematics as a growing, changing field that, like science, invents new knowledge?*

Popular American culture incorporates scientific questions. These may be presented in newspaper reports and on television, and lay people are even encouraged to develop explanations, conjectures and theories. By contrast, there is little evidence of current advances in mathematics. Our students have little sense that mathematics has its own compelling questions. In what may be characterized as a deeply anti-mathematical culture in the United States, how can we make mathematics more visible?

3) *How can we make it possible for students to learn to ask their own mathematical questions and pursue their own mathematical investigations?*

All three students we reported on held rigid and limited notions of mathematics. They felt that they had access to some computational algorithms, but little more. This made it nearly impossible for them to ask their own interesting mathematical questions, since they had no context for understanding the nature of mathematical questions.

How can we learn to parallel science education's ability to engage students by helping students pose their own mathematical questions and develop their own mathematical investigations designed to answer those questions? In short, how can we help students to think and act mathematically?

Recommendations: These questions leave us with the recommendation that mathematics educators must acknowledge the narrow, decontextualized view our preservice methods students often hold about the nature of mathematics, and develop some thoughtful responses to begin to counteract it. If we do not, we will not be able to move the field forward as quickly as we would like.

We also have a renewed confidence in the promise of combined mathematics and science methods courses for providing new models to students whose mathematics experiences have been limited. Some aspects of science (investigations, developing questions) seem to help students continue to wonder about the nature of mathematics. We suspect it works both ways.

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