DOCUMENT RESUME

ED 395 785 SE 058 369

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TITLE College Science and Mathematics Teaching Faculty Talk about Science and Mathematics: An Examination of the Role of Discourse in an Upper Elementary/Middle-Level Teacher Preparation Program.
SPONS AGENCY National Science Foundation, Arlington, VA.
PUB DATE 8 Apr 96
CONTRACT NSF-DUE-9255745
NOTE 53p.; Paper presented at the Annual Meeting of the American Educational Research Association (New York, NY, April 8-12, 1996).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS College Faculty; *Discourse Analysis; Higher Education; *Mathematics Teachers; Observation; *Science Teachers; *Teacher Attitudes

ABSTRACT

This research employs a mixed theoretical perspective drawing on elements from interactionism and social constructivism. In this study, a discourse analysis is performed on conversations among intra- and inter-institutional mathematics and science teaching faculty participating in reforming content classes for teacher candidates in the Maryland Collaborative for Teacher Preparation (MCTP), a National Science Foundation funded project. The goal of this study was to begin the process of painting a picture of the discourse landscape that higher education math and science teachers inhabit when the referent in their thinking is science and mathematics, two disciplines the MCTP project hopes to connect. The assumption is that this information will assist in understanding math and science teaching faculty's beliefs and actions taken in designing and teaching undergraduate teacher preparation science classes in which drawing connections between mathematics and science is a major goal. Discussion focuses on: (1) the comparison between the discourse on science and mathematics by mathematics/science content specialists versus mathematics/science methods specialists, and (2) the impact of collaboration upon the teaching faculty's discourse on mathematics or science, whichever is not their primary discipline. Contains 29 references, 4 tables, and 3 figures. (Author/SW)

College Science And Mathematics Teaching Faculty Talk About Science And Mathematics: An Examination of the Role of Discourse In An Upper Elementary/ Middle-Level Teacher Preparation Program

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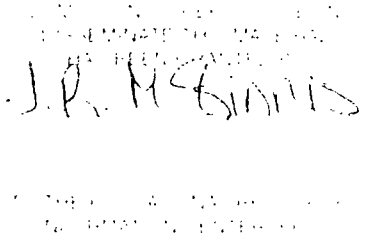
A paper presented at the annual meeting of the American Educational Research Association, New York City, New York, April 8-12, 1996.



The Preparation of this manuscript was supported in part by a grant from the National Science Foundation. (NSF Cooperative Agreement No. DUE 9255745)

College Science And Mathematics Teaching Faculty Talk About Science And Mathematics: An Examination of the Role of Discourse In A Middle - Level Teacher Preparation Program

Abstract

This research employs a mixed theoretical perspective drawing on elements from interactionism and social constructivism. In this study, a discourse analysis is performed on conversations among intra- and inter-institutions' mathematics and science teaching faculty participating in reforming content classes for teacher candidates in the Maryland Collaborative for Teacher Preparation [MCTP] an NSF funded project. The goal of this study is to begin the process of painting a picture of the discourse landscape higher education science teachers inhabit when the referent in their thinking is science and mathematics, two disciplines the MCTP p oject hopes to connect. The assumption is that this information will assist in understanding the science teaching faculty's beliefs and actions taken in designing and teaching undergraduate teacher preparatory science classes in which connections with mathematics is a major goal.

Discussion focuses on two areas: (1) a comparison of the discourse on science and mathematics between mathematics/ science content specialists and mathematics/science methods specialists, and (2) the impact of collaboration on the teaching faculty's discourse on mathematics and science, the 'other' discipline with which they are striving to make connections in their undergraduate classes.

College Science And Mathematics Teaching Faculty Talk About Science And Mathematics: An Examination of the Role of Discourse In An Upper Elementary/ Middle-Level Teacher Preparation Program

Introduction

The notion of collaboration has become an important idea in the field of education. A number of recent studies have investigated the classroom culture with an underlying assumption that learning/teaching is a collaborative effort involving teachers and students (see, for example, Cobb, Wood, Yackel, & McNeal, 1992). This development is consistent with the basic premises of the social constructivist perspective of learning/teaching (Bruffee, 1986; Gergen, 1985) which has become widely accepted in the education research community.

Because teacher development is also a process of learning/teaching, and because being a teacher involves a wide range of knowledge (Shulman, 1987), understanding the role of 'collaboration' in teaching and learning is crucial. A number of recent reform documents (see, for example, American Association for the Advancement of Science [AAAS], 1994; National Council of Teachers of Mathematics [NCTM], 1991) call for collaborations among colleges, K-12 schools, business, and government agencies in preparing future teachers. Since 1993, the National Science Foundation [NSF] under the Collaborative for Excellence in Teacher Preparation program has awarded several highly funded grants to projects which aim to reform undergraduate mathematics and science teacher education.

In this research study, a discourse analysis is performed on conversations among intra- and inter-institutions' mathematics and science teaching faculty participating in reforming content classes for teacher candidates in the Maryland Collaborative for Teacher Preparation (MCTP), a NSF funded Collaborative project. The goal of this study is to begin the process of constructing a picture of the discourse landscape college mathematics

and science teachers inhabit when the referent in their thinking is science and mathematics, two disciplines the MCTP project hopes to connect. The assumption is that this study will assist in understanding the teaching faculty's beliefs and actions taken in designing and teaching undergraduate teacher preparatory science classes in which connections between mathematics and science is a major goal. Research in teacher beliefs and actions have been a major focus of teacher education research since Clark and Peterson (1986) and Munby (1986) alerted the research community to its importance in understanding teaching practice.

Theoretical Perspective

This research employs a mixed theoretical perspective drawing on elements in interactionism and social constructivism. This theoretical perspective is thought to be consistent with a focus on the documentation and sense-making of collaboration among differing speech communities.

Interactionism posits that individuals communicate meanings of experiences by inventing symbols within a cultural context (Cobb & Baursfeld, 1995). Invented symbols include units of commu 'cation called speech, talk, discourse, or registers (Roth & Tobin, 1996). These symbols sustain and contribute toward defining and conducting social life within a defined population (Alasuutari, 1995; Gee, 1990; Lave & Wenger, 1991). Social constructivism asserts that the construction of understandings of experiences is a socially mediated act (Bruffee, 1986; Gergen, 1985). As a result, much emphasis in this study is placed on documenting and sense-making conversant communication by the precepts of interactional analysis.

Definitions And Methodology

Discourse as used in this study is defined as the dynamic interplay of dialogue between individuals that includes the use of rules developed by certain groups of people (Gee, 1990). The focus on discourse in this study is the result of recent theoretical views

that stress the importance of the context in which members of a community communicate (Greeno, 1991; Rogoff, 1990; Roth & Tobin, 1996). Conversations, or `talk,' is recognized as a particularly revealing resource in analyzing social interactions for patterns of sense-making in a community (Lemke, 1990; McCarthy, 1994). Talking is a communicative event in which the conversants collaborate in simultaneously constructing a social text and an academic text (Green, Weade, & Graham, 1988). The social text is defined as the agreed upon rules and purposes for the social interactions. The academic text is defined as the content of the discussion.

In the Maryland Collaborative for Teacher Preparation, the large speech community consisted of college faculty members who taught revised mathematics and science undergraduate content classes at universities, colleges, and community colleges in Maryland. Mathematics and science content expertise and an expressed interest in reforming content classes for MCTP teacher candidates defined the academic membership in the teaching faculty speech community. Sharing ideas on the role of mathematics and science in MCTP undergraduate content classes served as the purpose of the social text. In each of these speech, or discourse communities there were two groups: discipline content experts (termed 'mathematician or science content specialists' by the conversants in this study's speech community) and pedagogy content experts (termed 'mathematics or science methods specialists' by the conversants in this study's speech community). Figure 1 contains a diagram of the MCTP speech community identifying its constituent groups and the conversation referents under scrutiny in this study, science and mathematics.

Insert Figure 1 About Here

A qualitative methodology (Alasuutari, 1995; Erickson, 1986; LeCompte, Millory, & Preissle, 1992) was used to interpret conversation text supplied by audiotaped and

transcribed interviews of individual faculty members conducted throughout the 1994-1995 academic year. Faculty interviewed were members of the MCTP science teaching faculty who taught MCTP mathematics and science content classes at six of the participating institutions of higher learning in Maryland. In addition, two large group interviews of the faculty who taught MCTP mathematics and science content classes, respectively, were conducted during the summer of 1995. Both of these collaborative conversations were videotaped and transcribed. Participants included mathematics and science content specialists and discipline methods specialists. All are given pseudonyms in this study.

The software program NUD.IST was used to assist in chunking transcribed interview data into the speech communities by institutional job description titles that were involved in the MCTP teacher preparation classes (scientist, mathematician, science educator, and mathematics educator). It also assisted in the labeling and the retrieval of instances of conversation on the communication referents of interest: mathematics and science. Refer to figure 2 for a graphical display of the tree index analysis as conducted in the NUD.IST software environment.

Insert Figure 2 About Here

Context of Study

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary/ middle level teachers. The goal of the MCTP is to promote the development of teachers who are confident teaching mathematics and science, and who can provide an exciting and challenging learning environment for students of diverse backgrounds. A fundamental feature of the MCTP is the notion that faculty transformation and teacher preparation is contingent on participant collaboration.

The MCTP consists of the following:

- Specially designed courses in science and mathematics, taught by instructors committed to a hands-on, minds-on interdisciplinary approach.
- Internship experiences with research opportunities in business, industrial and scientific settings, and with teaching activities in science centers, zoos, and other institutions.
- Field experiences and student teaching situations with mentors devoted to the interdisciplinary approach to mathematics and science.
- Modern technologies as standard tools for planning and assessment, classroom and laboratory work, problem-solving and research
- Placement assistance and sustained support during the induction year in the teaching profession
- Financial support for qualified students.

History of the MCTP

The National Science Foundation selected Maryland in 1993 as one of the first three states awarded Collaborative Teacher Preparation Grants (spread out over a five-year period) to develop and implement an interdisciplinary program for intending elementary and middle school teachers to become science/mathematics specialists. Higher education institutions involved in this grant include ten colleges and universities in Maryland. Public school districts involved include Baltimore County and Prince George's County. The project management team consists of Jim Fey, Project Director, Co-Principal directors Genevieve Knight, Tom O'Haver, and John Layman, and Executive Director Susan Boyer. Various committees working on the MCTP include the Content Teaching Committee, the Pedagogical Committee, and the Research Group. These committees are charged with developing and researching new college-level content and methods courses for recruited teacher candidates who started in the program in the fall of 1994.

Participating faculty engaged in MCTP summer meetings at various colleges and universities during 1993, 1994, and 1995. During those extended meetings (several days and nights at a time) they collaborated in small content groups (physical science and biological science) to develop teaching modules which could be used in existing and new content classes. They also attended large group meetings in which topics such as constructivism were discussed. Throughout the intervening academic school years, participating faculty communicated with each other over the project's LISTSERV. They also met once each year between fall and spring semesters to engage in course debriefings. During these debriefings, the focus was on individual presentations by members of the mathematics and science teaching faculty. Limited discussion was conducted. The central leitmotif of the conversations was the tension between content coverage and the time required to enact the more student-centered, constructivist pedagogy promoted by the MCTP leadership. One scientist stated after the winter debriefing,

> A complaint that we heard from most of the people that taught courses that we spoke with, and to a certain extent it happened to us, was that we planned an amount of material that we thought was very easily manageable during the semester, and we didn't get anywhere near accomplishing what we thought we would. And I think in some ways that's because we...we had a difficult time teaching the course the way we wanted to teach it for MCTP and still being hung up on teaching it the way we probably would have taught it before. (Biologist, 2/95)

Findings

This section is divided into six sections. Section one contains the mathematics teaching faculty's individual talk about mathematics. Section two contains the mathematics teaching faculty's individual talk about science. Section three contains the science teaching faculty's individual talk about science. Section four contains the science teaching faculty's individual talk about mathematics. In these sections, the speech communities are analyzed

by two groups: (i) mathematics and science content specialists (scientists and mathematicians) and (ii) mathematics and science methods specialists (mathematics and science educators). Sections five and six contain the mathematics and science teaching faculty's collaborative talk about the 'other's' content discipline, science or mathematics, respectively.

Section One: MCTP Mathematics Teaching Professors Individually Talk About Mathematics

Throughout the 1994--1995 academic year, faculty teaching mathematics content classes at five institutions of higher education within the project were interviewed multiple times (n = 7, 5 mathematics content specialists, 2 mathematics methods specialists). In those audiotaped and transcribed individual semi-structured interviews, faculty were asked questions that prompted them to talk about mathematics. What follows are the conversation referents they made to mathematics.

Group one: Mathematics content specialists

Mathematics is different topics

> Now, as we go through this phase, at some point someone will announce that they're either going to be taking a course in *statistics* or a course in *calculus*. [italics added]. (mathematician, 10/94)

Mathematics is hierarchical

> The focus of the course is really on addition...you know, the basic operations--addition, subtraction, multiplication and division of numbers--and a lot of the material is, you know, real elementary, and it doesn't...it doesn't lend itself too well to scientific applications.... See, I'd hoped originally to not spend the usual...well not spend the whole semester on this stuff, but save, you know, a good bit of time at the end to do some functions, theoretic stuff, some modeling

stuff... we even thought about doing some real intuitive calculus. It's just not gonna happen. There's no point in pretending. (mathematician, 10/94)

Mathematics is a body of knowledge/content

I'm just hoping that these students are good enough to pick up the content about 25 percent faster than the students in the other sections. Now if these are students that are really suited by aptitude and inclination for mathematics and science, they ought to be able to handle to content faster than in the other sections....So that means I can't take content out, I just have to cover it faster.... And that's what I'm doing. (mathematician, 10/94)

Mathematics is a form of reality

Every single day they have...they are handling something where they are creating the math...the math reality. They're cutting open a paper cylinder and flattening it out so that they can see that the lateral face of a cylinder is a rectangle, and they measured circles, the circumferences of circles, and the diameters of circles, and discovered for themselves that Pi is simply the ratio between the two. So, any of the math facts that we are exploring from that curriculum we're going at from a discovery point of view. (mathematician, 3/95)

Mathematics is a form of logic

And the problems are chosen so that they are phrased that way, and even if they weren't phrased that way totally, that's the expectation, and it's just not acceptable to simply, you know, give a numerical response, that the whole exercise is in demonstrating a logic and the concept behind it, and the testing is...is to be the same....You know, what do you feel are the most important advantages for getting

students to write out their math logic as opposed to simply producing the answer? (mathematician, 3/95)

Group two: Mathematics methods specialists

Mathematics is a cognitive endeavor

It would be interesting to know six months from now what image of...how the course influenced their image of what mathematics is because that's certainly one of the things I was trying to do. I'm continually surprised this semester again at how much the students see this as so different than their image of math, and they quite often say things like, "You know, have to really think critically. You have to think in this course." (mathematics educator, 12/94)

Mathematics is modeling

I guess in all sections of the course, I tried to use the notion of a mathematical model--and I suppose before [this project], I would have said, "Point out to the students..." but now I have to be careful that I don't say that--try to get students to recognize the way...the power and the limitations of these mathematical formulations as a way of thinking about situations. And so, in that sense, I guess I'm...I was asking them to reflect on the nature of mathematics and the usefulness of mathematics and so on. (mathematics educator, 12/94)

I think they also got a sense that as mathematics is fitted to a variety of problem situations, that the fit is never perfect, that you don't get too bent out of shape about that, and that you expect some of the data points won't be on the curve, that they also got the...in a modest way the sense that if you want to make projections, that some models will be better than others.... (mathematics educator, 12/94)

Mathematics can define people's personal

> I wonder whether there's a difference in the personality of mathematicians, you know, a difference in mathematicians and scientists in their personality and emphasis? We may be glass half empty people and they are glass half full people....I'm always worried about what [students] didn't get you know. I worry about the student that's just totally lost in the material, just can't get it, sitting there....The thing about mathematicians [is that they] have this more analytic, prove it rigorously, make sure everything is defensible kind of thing, we don't deal with soft-edged things. (mathematics educator, 12/94)

See table 1 for a summary of the mathematics teaching faculty's talk about mathematics.

Insert Table 1 About Here

Section Two: MCTP Mathematics Teaching Professors Individually Talk About Science

Throughout the 1994--1995 academic year, faculty teaching mathematics content classes at five institutions of higher education within the project were interviewed multiple times (n = 7, 5 mathematics content specialists, 2 mathematics methods specialists). In those audiotaped and transcribed individual semi-structured interviews, faculty were asked questions that prompted them to talk about science. What follows are the conversation referents they made to science.

Group one: mathematics content specialists

Science is found in nature

I'm going to try to incorporate at least parts of some of the modules that were done this summer, but even there some of the ones that I'm gonna use don't have many...many scientific applications. I've done, in looking at sequences so far, I've...we've got a.... I've managed to get a little bit of science in; we looked at Fibonacci numbers and some occurrences in nature. (mathematician, 10/94)

Science is substances

And the one that probably, overall, produced the most fun and comment was the balloons that we did that we called the "Fweebles from the Planet Arbitron"--different colored balloons with different gases. (mathematician, 10/94)

Science is theories and predictions

We were supposed to come up with scientific theories to explain what was going on. I kept pulling out more and more colors and more and more things. Predict what's gonna happen. Some of the predictions would work, some wouldn't. We'd keep modifying the theory and modifying the theory...(mathematician, 5/95)

Science is tentative

I had sort of an explanation of what science is, and how it works, and how, no matter what you've been able to explain so far, you could still be wrong. And that...when we did that it was sort of a summing up of, you know what is science. (mathematician, 5/95)

I said, "When I was in school, and it's not that long ago, there were, you know, two types of life, two kingdoms--plants and animals. Now there are five, and the

reason is we can better explain what we see with five than we could with two. What will it be, you know, in 20 years? Will there be seven? Will there be three? It depends on what we've discovered in the meantime and how it best seems to fit together. But we shouldn't necessarily be upset that it's going to change, that it's...it's a reflection of our current knowledge." ...I think one of the biggest things that we've probably gotten across to them, and it was a shock, and they've expressed it various ways, is the notion that science is so...so dynamic, and what is scientific truth is changing so rapidly and so constantly, that really it's under assault all the time, and that you really can't say "this is a fixed idea that's going to last for any length of time, it could change tomorrow." (mathematician, 12/94)

Science is a way of knowing/a view of the world

I think the biggest frustration to me and perhaps the most interesting part was that they viewed what we were doing in some cases as providing answers to questions rather than providing a way of looking at things. (mathematician, 5/95)

Something like that as going on, and, we want to figure out ways to do more to at least force them to at least temporarily adopt a scientific mind-set. (mathematician, 5/95)

I thought we were doing a better job than we did, you know, in terms of what we were getting across, and I think that the kids viewed it as content or answers to questions, and we viewed it more as the philosophy and from the point of view of mind-set, a view of the world or whatever. And they could accept the fact that we had that view of the world, but they didn't want to have it themselves. (mathematician, 5/95)

Science explains the experiential world

> Here's what we see in the sky, why has that happened, and not talk about things, like, well we know that this planet revolves around the sun. We said, "No, no, the Greeks didn't think that. The Greeks said this. Now how did they explain it?" (mathematician, 5/95)

Science is a type of truth

> The facts are a lot less important than the philosophical view they'll have then of...of science, and scientific thinking, and scientific truth, whatever that is. (mathematician, 5/95)

Science is a human construction

> One of the silly ones we did early on was really fun with a collection of beans. You know, they had to classify this pile of beans, and nobody got what we...what we call the scientific classification or the standard one, but several of them got some rather interesting ones, and very reasonable and very rational. And the idea there was no...not necessarily a fixed answer that we were looking for kind of intrigued them. You know what we did? We had them switch around and said, "Okay. Now, how did this person divide them up? Can you tell their patterns from their piles, what their scheme was?" In some cases you could tell and in some cases you couldn't, and they had to explain it." But...well, the idea that the classification was very arbitrary was something they really, really hadn't expected. They always think--again, all but one, I think--expected that science had the answers.... And we're trying to get across the fact that science has the answers within certain constraints, and part of it is this classification scheme. (mathematician, 12/94)

Science is many disciplines

> ...we emphasized we want more than just a single area so that they're relating this to, you know, to biology, to chemistry, and to geology and whatever. (mathematician, 12/94)

Group two: pedagogy content experts

Science is patterns in the physical environment

> ...when I started the exponential unit, for some reason I felt that we hadn't done anything where they actually had done some hands-on activities for a while, and so I did a bunch of stuff with beads and sampling, and the replacement things like removing pollution--simulation of removing pollution--and a simulation of growing populations and stuff.... that whole set of activities didn't work very well partly because in order to make them work well, you have to do the procedures fairly carefully, otherwise, the data just looks like mish-mash. You can't see anything in it. Whereas, I thought it was going to set up, some interesting different...different kinds of patterns here than we saw with all the linear stuff....(mathematics educator, 2/95)

Science is a context for problem solving

> Now, to me, what an ideal problem would be, a way to pose that would be here is the globe, here is the sun. Figure out how the earth moves around the sun, and how could we have seasons, and how could we have all these. (mathematics educator, 2/95)

> I took the students over to the sundial area yesterday, and a part of me would like to think, oh, they're gonna look at this kind of thing and think "what's goin' on?" They're interested in the angle of the shadow, and they're seeing the angle of that shadow, and this will tell us this, and this will tell us that, and they'll just sort of

immediately size up the situation and just go right to it. And of course they don't. I mean, they...they wander around, they look at where the shadow is, but they wait for the sun to come out to see where the shadow is... They've got to visualize the sun here, and the earth there, and the tilt of the axis, and... (mathematics educator, 12/94)

The overall theme of the course...the title of course is Elementary Mathematical Models, and the things we model are very often from science, but not always from science. And so most of the activities involve some setting, contextual setting, not like what you see on the board which leaves you with no context. (mathematics educator, 9/94)

We use the application of problems in the sciences. For instance, we had observations of using different kinds of rocks, and they made conclusions that rocks all sink.... We try to use real-life applications in the scientific world to try to model some of the ideas. (mathematics educator, 5/95)

See table 2 for a summary of the mathematics teaching faculty's talk about science.

Insert Table 2 About Here

Section Three: MCTP Science Teaching Professors Individually Talk About Science

Throughout the 1994--1995 academic year, faculty teaching science content classes at six institutions of higher education within the project were interviewed multiple times (n = 11, 8 science content specialists, 3 science methods specialists). In those audiotaped and transcribed individual semi-structured interviews, faculty were asked questions that

prompted them to discuss their understandings of science. What follows are the key conversation referents they made.

Group One: Science content specialists

Science is modeling observable phenomena

> It was really enlightening because the one group had real concrete examples that were.... She must write everything in here, somebody must write everything in her notes because you could hear it--[Bob] standing there saying, "When we make a model there's an assumption, we have to make an assumption." And that came back. An the other though, the other pair as we've paired them up this time were much more fluid and conceptual in their thinking...(Biologist, 2/95)

Science is progressive

> ...and we got to the end and they said, "But we still don't know if energy can have a particle nature of if matter can have a wave nature." Well, heck, folks didn't know that for a very long time, but I was just delighted that she...she said, "Should we know that? Should we have figured that out from what we did?" (Biologist, 2/95)

Science is specific topics

> This class was more planned to make connections between chemistry and biology, so we didn't do a whole lot of math this time, but in the end when were studying photosynthesis, we were measuring as the index of the rate of photosynthesis, we were measuring volume of oxygen produced. (Biologist, 5/95)

Science is compartmentalized into discrete disciplines

> On every comment sheet I've completed I've discussed the same issue, and it's

not been addressed. The earth and space sciences are not represented. We have only one geology and no astronomy specialists in the project ... I'm concerned about how content specialists have been picked; what is the logic to having only biology, chemistry, and physics represented? These are not the only sciences that there are. In the middle grades, earth science is taught - soils, rocks, planets, moons, meteorites. Whether MCTP produces specialists in math & science will be limited by the design they have chosen; it does not represent all of science. (Geologist, 2/95)

Science is information

And incidentally, one thing I learned this semester from working with [Bob] is that I think it was a problem for me and a mistake that I made the first semester being on my own is that I slowed down considerably. I didn't worry about having something going all the time, and I let it be more class curiosity driven and less driven by me always having something for them to do, or think about, or discuss. And I think that that made a more comfortable atmosphere for the students, and it certainly is, conducive. They probably get less information. I think I was trying to still...even though I had made a concerted effort to cut back on the information, I think I still tried to put too much into the first semester, so I have a lot of rethinking that I have done in terms of modifying that first semester course. (Biologist, 2/95)

Science is scholarship and an intellectual activity

...and that's not just in this course, but I think in a lot of courses, you know, especially someone who is...who is going to be a teacher needs to have an attitude about scholarship and intellectual activity and learning that is different from what they can get by with if they're simply looking for a grade. (Biologist, 12/94)

Science is experimenting

So they saw, I think, a very student-centered atmosphere both in the lab as well as in the lecture. The lab was very hands-on and concrete-oriented....And if they suggested an experiment, we set it up and gave them free lab where they could do whatever they wanted to. (Physicist, 3/95)

Well, their are cooperative exercises in the class. Of course, the lab experiments aren't unique because they're a standard part of science. (Chemist, 5/95)

My graduate students look at me with great puzzlement when I tell them about the things that I am involved with in this project. I mean, you know, they can't understand why in this world would you be doing that? It doesn't have anything to do with the particular labs down there, and that all my papers had to do with all these years....You know, they thought I was a different person. (Chemist, 5/95)

Group Two: Science methods specialists

Science is a lifelong process

...if you're doing the constructivist approach, there is no end point either for the teacher or the students, it's a lifelong process that by happenstance you and the students have shared for one semester (Science educator, 2/95)

Science is an inquiry that involves models and explanation

Yeah. I would hope that they would view science as inquiry, or science was a way of thinking, or inquiry as a way of thinking, and that I would see students gathering data about questions that either they had posed, or the teacher had posed, or the curriculum had posed, or that somebody had posed, and that they were trying to gather data and then trying to make some sense out of that data, trying to develop

models to explain what they had observed or somehow analyzing that and communicating what they had analyzed. Pretty tough to do. (Science educator, 3/95)

Science is questioning

One thing that I'm finding, and I don't know, I'm still new at much of this, but one thing I'm finding is if, in fact, we begin to take that big step to say, "Let me try to become immersed with constructivist principles," one doesn't really know where the topic will lead because if we really believe that it should be student directed in terms of what I want to know, or I want to know more about this, or I found this, is this going to be the same case? For example, with the germination domes there were students who said, "What would happen if I use artificial lighting as opposed to natural lighting?" Or, "...if I used my southwest window..." What am I trying to say? It was the south window, was it.... I'm trying to remember an example from a real experience here. At any rate, she was...her home was sort of on a slant or something, it wasn't straight, it wasn't directional, due north, or due south, or east, or west. But at any rate, she wanted to see what would happen with root structure, and the way certain seeds would germinate under those conditions. (Science educator, 6/95)

Science is content and process

And that's uncomfortable because.... Well, I was groomed with "You need to be steeped in your content as well as process." (Science educator, 6/95)

Science is a serendipitous thing

> And when I think about the real world and...and the work of some of the scientists, it is the serendipitous thing that might in fact provide some of the important responses to devastating questions which are out there.(Science Educator, 6/95)

See table 3 for a summary of the science teaching faculty's talk about science.

Insert Table 3 About Here

Section Four: MCTP Science Teaching Professors Individually Talk About Mathematics

Throughout the 1994- 1995 academic year, faculty teaching science content classes within the project were interviewed multiple times. (n=11, 8 science content specialists, 3 science methods specialists). In those audiotaped and transcribed individual semi-structured interviews, faculty were asked questions that prompted them to talk about mathematics. What follows are the key conversation referents they made about mathematics.

Group One: Science content specialists

Mathematics is something you can have or possess

> The students, they didn't feel prepared, but the manner we went about it, we had discussed and negotiated that this would be...they would be learning the mathematics, it was not necessary that they would be assumed to have it coming in. I told them I assumed that they had very little coming in. (Physicist, 5/95)

Mathematics is an equation for straight lines

Yeah. I did not assume that they knew the equation of a straight line. I assumed that they had heard that there is such a thing as the equation of a straight line and could probably parrot back Y=MX+B. (Physicist, 5/95)

Mathematics is terms

So we went further. We got into the quadratic equation, we got into polynomials, we got into exponential functions, and not in depth, but they did start curve fitting, you know, using the computer, and I had no intention of really getting that far into it, as well as some of the students went into a description of polynomials and degrees, and what that might have meant in terms of the curvature and the various terms in the lines. So I got in further than I thought I was going to get into. (Physicist, 5/95)

...the students were really making the connections and thinking, you know, in mathematical terms about a lot of what we did in class without...without needing to be prodded that way. They also...they would remark in class, "Gee, we were just doing these things in math. You know, we feel comfortable with that, we're experts now in this area." You know, that makes you feel good about it. And I think they felt good about it. (Biologist, 10/94)

Mathematics is calculations

Well I teaching genetics right now, and that is very much mathematically based primarily via the simple laws of probability are being employed. And what I have done to try to stress that basis is to not allow the kids to use the sort of classic punnett square, which is really just another way of...of doing probability, but I've made them do the mathematical calculations, and we did that for a whole week

before I showed them the punnett square, which most of them had been introduced before anyway, and then we talked about the foundation of that, and why you can use that, so that...that's basically what I've done so far. (Biologist, 10/94)

And then the end of the class had to do with evolution, and that's just simply applying the laws of probability and the same sorts of things that we learned in genetics, but rather than to individuals, to populations. I would often have them calculate probabilities of some event, or I had them for instance calculate the number of possible genetic codes of triplets. (Biologist, 12/94)

When doing genetics, we looked at probability, we did calculations when determining the number of nucleotides in a hypothetical gene. We also did calculations, early on, during the course when looking at the chemistry of life and pH. (Biologist, 5/95)

Mathematics is measurements of data

As I mentioned, this class was more planned to make connections between chemistry and biology, so we didn't do a whole lot of math this time, but in the end when were studying photosynthesis, we were measuring as the index of the rate of photosynthesis we were measuring volume of oxygen produced. (Biologist, 5/95)

Mathematics is problem solving

Well, we had problem solving in the physical sciences in the areas of physics and chemistry....that's where the math connection is, in the physics and chemistry. (Physical scientist, 5/95)

Mathematics is basic operations

I spent quite a bit of time on such topics as molecular geometry and symmetry, which involves 3D visualization and spatial thinking. Also, we frequently used basic operations such as units conversion, measurement, ratio, proportion, logarithms, exponents, area and volume calculations, counting vs. weighing ("how much" vs. "how many"), as needed throughout the course (Chemist, 12/ 94)

Mathematics is a tool to do science

I had planned to do a good bit of that connection [mathematics and science] in this chemistry class. Of course, that's from the point of view, natural point of view, that I would take as a scientist as math as a tool to be used, as opposed to math to be developed. (Chemist, 12/94)

Mathematics is quantification of qualitative explanations

I can't tell you anything in particular, but I think that the plan as far as both of us are concerned is to continue to make those connections wherever we can and also to present the science we present in as quantitative a way as possible. (Biologist, 10/ 94)

It was a comment that the book made in a qualitative sense and I felt that this was something we could attack in a more quantitative way. (Chemist, 12/ 94)

With every topic, mathematics is being addressed: write a mathematical expression for the phenomenon; graphical representation of phenomenon....(Geologist, 2/95)

Mathematics is really more than as is perceived by scientists

Measurement in units, units of measurement, unit conversions are a bit of a stumbling block, you know, how many centimeters are there in a half of meter, something like that, you know, that sort of thing. Those are, I would have thought, fairly basic things but they're challenging to the student. So you know, that's, but you know, I still look at that as being fairly weak kind of excuse for connections between math and science, but if they have trouble with that, then, I'm not sure I could, how much success I would have doing something that a mathematician would truly feel as satisfying mathematics. Part of it is that I really don't know what mathematicians would say is math. What is satisfying mathematics from their point of view. But there's no question. The student's would prefer there are no connections. Many of them would prefer that there are no connections between science and math because a lot of them don't like it. I had one student who just, you know, flat out said he doesn't like math, doesn't want to do it and wants to avoid it and please don't do any math in this course.
(Chemist, 12/ 94)

Yeah, well, I guess I see that I'm going to, basically we're still on Chapter One and I already see that particularly the mathematically part, I mean, just really, tool using kind of mathematics which is not, I recognize probably very interesting mathematics to the mathematician but those things are a challenge to the students already and the book has a good bit it more of that. I suspect I'm going to have to scale back a bit on some of my expectations here but on the other hand, you know, I want, I would like to be able to integrate more mathematics. Maybe I need to broaden my concept of what mathematics, what constitutes mathematics....
(Chemist, 12/94)

Group Two: Science methods specialists

Mathematics is the visual display of data (e.g., graphing, charts)

> We have achieved that at a moderate level and primarily through the use of the microcomputer-based labs and the graphs that are produced...We had moderate success in the use of the graph as a means of relating the science to the mathematics. (Science educator, 12/ 94)

> So, it's a very rich array of physical behaviors represented by the transformation into the graph...which is REAL STUFF! Real distances, real velocities, real accelerations that they can make reference back to their own personal decisions in the case of their own personal motion, or describe the behavior of the fan cart (Science educator, 9/ 94)

> Students were involved in several long-term projects which gave them opportunities to conduct a variety of observations and to collect data and then to translate that data, chart that data, in a variety of ways.... see the need to be accurate, or to display the information as succinctly as possible and so on. (Science educator, 6/95)

Mathematics is a tool to be used (not to fundamentally understand)

> What we do is just make math a part of our data analysis, so we do a lot of data analysis, plus we do some model development. In science, for example, the heat energy unit which looks at areas and conservation of area, so that's kind of mathematically developed as well. ...So it's not specifically designed to highlight the relationship, we just simply use the mathematics. (Science educator, 5/95)

See table 4 for a summary of the science teaching faculty's talk about mathematics.

Insert Table 4 About Here

Section Five: MCTP Mathematics Teaching Professors Collaboratively Talk About Science

During the summer of 1995, the mathematics teaching faculty participating in the MCTP project attended a project conference. At this conference, the mathematics teaching faculty who were present (n = 5, 2 mathematics content specialists, 3 mathematics methods specialists) participated in a group interview in which they discussed science, the 'other' discipline with which they were striving to make connections in their MCTP classes. What follows are the key referents to science in the chronological order they unfolded in the conversation.

Science includes mathematics

> We've always said that mathematics was the queen of all sciences, and some of us even say that we want to talk about the mathematical sciences, so I think we ourselves are part of science. I think science is an organized structure, it's the same as mathematics. It has its language. It has its syntax. It has its structure. People have an opportunity to explore new ideas and to kind of verify or refute or support conjectures and so forth. So if you look at us in a parallel sense, I think we have many similarities with it. (mathematics educator, 6/95)

Science is different from mathematics

> Well, I think there is a fundamental difference in the way mathematics is done and the way science is pursued. There's a difference in the process of validation. (mathematician, 6/95)

I think there is a place where math and science are a little bit different. Math is more than just its connections to science. (mathematics educator, 6/95)

. was going to say that a piece of mathematics can be applied in more than one place, and that's an argument that we can get into, this whole business of what mathematics is. Every time we talk to the scientists, they say, "Oh, good, you're going to have more connections." And somehow the connections to the math kind of disappears because the essentials of organizing the mathematics in its own right is the part that they tend to want to leave out. (mathematics educator, 1995)

Science deals with the physical world

Science deals more with tangible phenomena that you can touch, and feel, and see, whereas, mathematics deals with phenomena that are more abstract and mental. (mathematics educator, 1995)

Science is useful to mathematics because it provides student motivation and problem contexts

In teaching, also, I think but in actual real-world fact, science has provided tremendous numbers of problems for us. It has provided motivation. When you go to a conference and somebody says, "Why do you want to look at this?" and they say, "Well, it's related to this, and this, and this. And if some of that isn't science, we're not interested." (mathematician, 6/95)

I know in courses sometimes we talk about sequences, and series and so forth. We can go out in nature and find things that are happening in the ocean or happening...that were really...is a perfect representation of what it is that we are

trying to do in mathematics. Sometimes we claim that mathematics is a tool, and it's a very useful tool. Because without this tool, a lot of things would not happen. If you think about it, almost everything in life is based on mathematics. Science sometimes gives us, you want to say, that vehicle, that representation that we can see things happen. Especially with people who don't like mathematics, or young children, they can get excited about seeing the different shapes.... So science really plays a very, very important part with us as teachers because we need something sometimes to attract or introduce the non-believer or the person who has a very poor image of myself, "I can't do that stuff." But if you do it for something that's in the sciences, they might get interested. (mathematics educator, 6/95)

Section Six: MCTP Science Teaching Professors Collectively Talk About Mathematics

Also during the summer of 1995, the science teaching faculty participating in the MCTP project attended a project conference. At this conference, the science teaching faculty who were present (n = 7, 6 science content specialists, 1 pedagogy content specialist) participated in a group interview in which they discussed science, the 'other' discipline with which they were striving to make connections in their MCTP classes. What follows are the key referents to mathematics in the chronological order they unfolded in the conversation.

Mathematics is a tool

Obviously, mathematics is a tool in support of science conceptual understanding, and science dips into it and uses it as needed.... (Science educator, 6/95)

Mathematics is more than a tool

I used mathematics as a tool without worrying about honoring the mathematics viewpoint, but now I do, you know, because of this collaboration. I'm now aware that there is this other point of view that I need to honor in an integrated course, and that is a challenge for me. (Chemist, 6/95)

Mathematics is characterized by its intrinsic logic and beauty

Before MTCP, I regarded mathematics as strictly a tool, or a language, or both. After MCTP we have come, or at least I have come to appreciate, math more in terms of its intrinsic logic, its beauty, and a challenge to teach it, and I appreciate some interconnectedness that I did not really, you know, appreciate. (Biologist, 6/95)

To truly understand mathematics, you need to be informed by a mathematician

But one of the things we're going to specifically work on in the next month is trying to make those very deliberate points where new concepts and skills can be developed, and we're using a mathematics education person at [our institution] is to try to address that much more consciously.(Geologist, 6/95)

Well, I will say, from the biologist's point, that I realize the importance of math, that it is actively essential. But I think that during this summer as I rework the syllabus for the biological science that I will definitely be talking to a mathematician for ways to integrate it more. (Biologist, 6/95)

Mathematics does not need science as a discipline (but science does need mathematics as a discipline)

The students do not appreciate the fact that math as a discipline does not need science, but science as a discipline absolutely requires math.... I don't think there's

a mutual need. I think we would like to present an integrated approach to both scien[illegible]nd math. But the mathematician can be very happy, thank you, without having science.... my perception is that the core of mathematics is without science. I think because we're so practical minded we want to see its applications, we think well it only become illuminated when it's applied to an scientific problem. (Biologist, 6/95)

I would say that probably all of us are extraordinarily skillful at using mathematics, and we have multiple opportunities to use mathematics in a profitable way. What I feel uncomfortable with is that's not all there is to mathematics. I don't have the mathematician's view of math as a system of thought as opposed to a tool and language. (Biologist, 6/95)

Discussion/Implications

Discussion focuses on two areas: (1) a comparison of the discourse on science and mathematics between mathematics/science content specialists and mathematics/science methods specialists (2) the impact of collaboration on the teaching faculty's discourse on mathematics and science, the 'other' discipline with which they were striving to make connections in their undergraduate content classes.

A comparison of the mathematics content specialists' and the mathematics methods specialist discourse on mathematics reveals that they express different referents to mathematics in the same speech community. In this study, the definition of speech community membership is taken from Green, Weade, and Graham (1988). It consists of two types of text: social and academic. In this study, the social text was defined as the sharing ideas on the role of mathematics and science in MCTP undergraduate mathematics classes. The academic text was defined by the mathematics teaching faculty as mathematics content expertise and an expressed interest in reforming content classes for MCTP teacher

candidates. In discussing mathematics, individuals in the mathematics content group referred to mathematics as an immense, hierarchical and logically structured body of knowledge which existed as a separate reality transcending the physical universe. In contrast, individuals in the mathematics methods group referred to mathematics as modeling the physical universe and as a telling determinant of a person's personality or worldview. Those in mathematics were posited to be distinguished by an outlook in which their perspective on water in a glass is "half-empty" rather than "half-full" and by a need to employ analytic rigor to prove things and not to "deal with soft-edge things." (interview, mathematics methods specialist, 12/94). In both groups the notion of mathematics as something that existed in the mind that was linked with thinking was expressed.

In discussing science, both the mathematics and the mathematics methods content groups expressed that science is linked with the physical universe. This was expressed as science as being found in nature and in particular substances (such as "gases" or "rocks"). Individuals in the mathematics groups differed in several ways in which they referred to science. The mathematics content group expressed a broad array of referents to science, many of which were linked to its structure as a discipline as constructed by humans over time. Science was referred to as a type of "truth," a "mind-set," and as "theories." This was in contrast to individuals in the mathematics methods group who expressed a utilitarian vision of science as defined through a mathematics filter: science provided a motivation and a physical context for the doing of mathematics.

A comparison of the science content specialists' and the science methods specialists' discourse on science reveals both similarities and differences on this same referent within the same speech community. In this study, social text was defined as sharing ideas on the role of mathematics and science in MCTP undergraduate science content classes. The academic text was defined as science content expertise and an expressed interest in reforming content classes for MCTP teacher candidates. In discussing science, a similarity between some members of the groups was the belief that science is

characterized by modeling of physical phenomena. Key differences between the groups discussing science involved some members of the science content specialist group expressing the beliefs that science is information, compartmentalized into discrete disciplines, and specific topics while some members of the pedagogy content specialist group expressed that science consisted of content and *process*, the way of doing science. In discussing mathematics, a similarity between some members of the groups was that mathematics is a tool to be used in science. Key differences between the groups discussing mathematics involved some members of the science content specialist group expressing the beliefs that mathematics is also terms, calculations, operations, the quantification of qualitative explanations, and that mathematics is really more than as is perceived by those engaged in doing science.

The findings that similarities and differences exist in how science and mathematics are perceived between these groups which compose the teaching faculty in the Maryland Collaborative for Teaching Preparation are significant. Firstly, the findings serve to document the conversation landscape found in the mathematics and science teaching faculty speech community. It is revealed that discourse within the speech community is cohesive in certain areas but not in others. It is informative to note in which groups composing the speech community certain beliefs are found. For example, in the case of referents to science, the belief that science is a body of information is a key referent as expressed by members of the science content specialist group. This can be contrasted with the belief expressed by members of the science pedagogy content specialist group that it is both a body of knowledge and a *process*, the way of doing science. Also, in the case of referents to mathematics, conversants in the science content faculty express the belief that mathematics is more than a tool, but this is not documented as being expressed by any members in the science methods specialist group. In the mathematics teaching faculty's speech community, a key referent for several individuals in the mathematics content group is that mathematics is an immense body of hierarchically structured knowledge that exists

outside of the physical universe. This is in contrast to the emphasis placed on the linkage of mathematics to human personalities and worldview by a member of the mathematics methods group. Even more striking is the contrast between the constituent groups in mathematics teaching faculty in how they refer science. Individuals in the mathematics content group refer to science as a discipline while individuals in the mathematics methods group refer to science as a motivation and context for doing mathematics.

These findings support and extend recent assertions that differences between content discipline experts and content methods experts tend to exist in how they conceive their content disciplines (Mura, 1993, 1995). In collaborative projects such as the MCTP in which both content and methods experts equally participate, and in which there are specific project goals that relate to making connections between disciplines and how they are taught, this recognition can assist project directors engage in sense-making and in devising strategies to implement project goals. For example, with the type of information supplied by this type of discourse analysis, energy and strategies can be targeted for specific groups (and members of those groups) composing the teaching faculty speech community which will promote and support faculty transformation in the direction toward a significant project goal, making connections between science and mathematics and teaching in a manner consistent with constructivist tenets. Certainly supporting the belief that science is both content and a process and that mathematics is more than a tool would assist in efforts to transform the teaching faculty's practices in this teacher preparation project.

Secondly, the findings assist in sense-making the dynamics of collaborative conversation within the MCTP teaching faculty and offers insight into how imperative collaboration is for faculty transformation (Bickel & Hattrup, 1995; Denton & Metcalf, 1993) Figure 3 contains a discourse analysis of the science teaching faculty's group conversation. It is informative to note that the initial referent made to mathematics was a belief expressed in both the scientist and the science education groups: mathematics is a

tool (refer to tables 3 and 4). The conversation then entered a catalytic state when a member of the science content specialist speech community expressed that he believed that mathematics was more of a tool. This belief had not earlier been noted in the science methods specialist discourse community but earlier had been detected in the science content specialist discourse community (see table 4). At that point, the conversation developed as members of the science content specialist discourse community expressed the new script that mathematics can be characterized by its intrinsic logic and that to truly understand mathematics, one must be informed by a mathematician. These statements are proposed as emerging new understandings in both groups composing the science teaching discourse community since neither had been earlier documenting as being expressed in this fashion. The conversation entered a termination state when a speaker proposed that mathematics does not need science as a discipline, but science does need mathematics as a discipline. Much disagreement in both the science and methods content specialist discourse groups was expressed and no new consensual domain formed (Maturana, 1978).

Insert Figure 3 About Here

In the discourse analysis of the science teaching faculty's collaborative conversation on mathematics, the impact of statements made by differing members of the teaching faculty speech community is revealed. Newer understandings of mathematics and science were constructed in social settings in which representatives of both groups (mathematics/science content specialists and mathematics/science methods specialists) in the teaching faculty speech community participated. This suggests that collaborative conversations can be critical to initiate inclusive changes in individual conversant's understandings of a referent (see, for example, Vygotski, 1986) and also to forge consensual domains in understanding of a referent among members of the collective speech community (see, for example, Maturana, 1978). A strong implication of these findings is

to place value on instances of collaborative discourse on beliefs among members of the teaching faculty participating in the MCTP.

Note: A similar discourse analysis of the mathematics teaching faculty's collaborative discourse is currently being conducted and will be presented in future reports. The complexity is greater due the power differential added because one of the conversants is the project's principal director. Prominent researchers such as Tobin (1996) point out that in social settings, power is a significant force that needs to be considered in interpreting participants' actions (which includes discourse).

Conclusion

This study documents and interprets discourse in the teaching faculty's speech community within the Maryland Collaborative for Teacher Preparation. Future research will focus on examining the large group teaching faculty's discourse on mathematics and science in venues in which both the mathematics and the science teaching faculty engage in conversation. Findings from this research focus will assist with sense-making in faculty transformation. In addition, on-going research is focused on examining the MCTP teacher candidates' discourse and on comparing their referents to mathematics and science and to the teaching/learning of mathematics and science with the teaching faculty's discourse. Findings from this research focus will assist with sense-making in the teacher preparation of mathematics and science upper elementary/middle-level specialists.

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Authors Note

We would like to acknowledge and express appreciation to Amy Roth-McDuffie, Mary Ann Huntley, and Karen King for their assistance in conducting interviews reported in this study. We also would like to acknowledge the technical assistance of Steve Kramer for the NUD.IST data analysis.

Table 1

Mathematics Teaching Faculty's Talk About Mathematics

Group	Conversation Referents
Mathematics content specialist	Mathematics is different topics
	Mathematics is hierarchical
	Mathematics is a body of knowledge/content
	Mathematics is different topics
	Mathematics is a form of reality
	Mathematics is a form of logic
Mathematics methods specialist	Mathematics is a cognitive endeavor
	Mathematics is modeling
	Mathematics can define people's personalities

n = 7, 5 mathematicians, 2 mathematics educators.

Table 2

Mathematics Teaching Faculty's Talk About Science

Group	Conversation Referents
Mathematics content specialist	Science is found in nature
	Science is substances
	Science is theories and predictions
	Science is tentative
	Science is a way of knowing/a view of the world
	Science explains the experiential world
	Science is a type of truth
	Science is a human construction
	Science is many disciplines
Mathematics methods specialist	Science is patterns in the physical environment
	Science is a context for problems

n = 7, 5 mathematicians, 2 mathematics educators.

Table 3

Science Teaching Faculty's Talk About Science

Group	Conversation Referents
Science content specialist	Science is modeling observable phenomena
	Science is progressive
	Science is specific topics
	Science is compartmentalized into discrete disciplines
	Science is information
	Science is experimenting
Science Methods Specialist	Science is a lifelong process
	Science is an inquiry that involves models and explanation
	Science is questioning
	Science is content and process
	Science is a serendipitous thing

n = 11, 8 scientists, 3 science educators.

Table 4

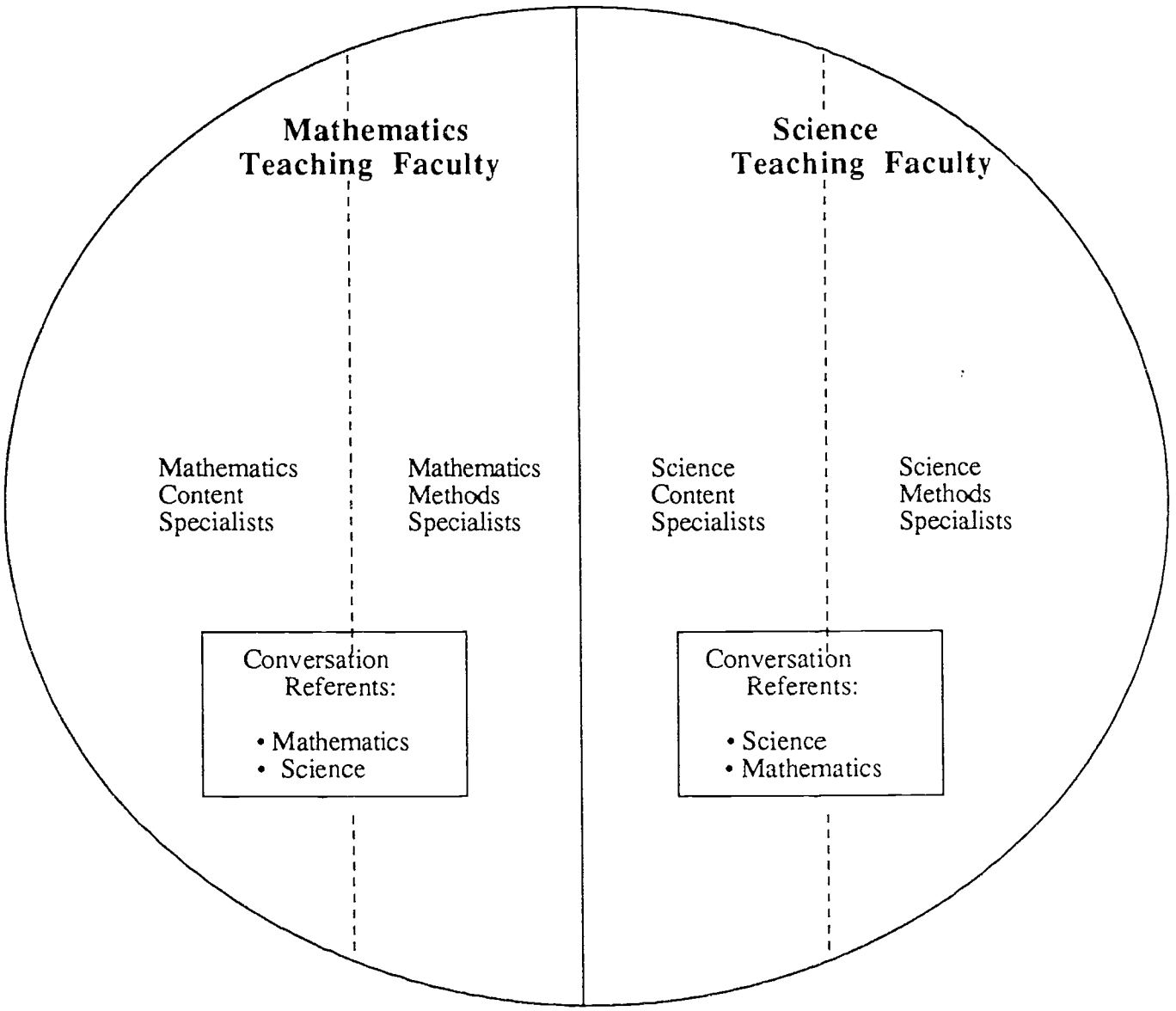
Science Teaching Faculty's Talk About Mathematics

Group	Conversation Referents
Science content specialist	Mathematics is something you can have or possess
	Mathematics is an equation for straight lines
	Mathematics is terms
	Mathematics is calculations
	Mathematics is measurements of data
	Mathematics is problem solving
	Mathematics is basic operations
	Mathematics is a tool to do science
	Mathematics is quantification of qualitative explanations
	Mathematics is really more than as is perceived by scientists
Science Methods Specialist	Mathematics is the visual display of data
	Mathematics is a tool to be used

n = 11, 8 scientists, 3 science educators.

Figure 1 Caption

Figure 1. Teaching faculty speech community in the Maryland Collaborative for Teacher Preparation Project.


Mathematics
Teaching Faculty
Mathematics
Content
Specialists
Mathematics
Methods
Specialists
Conversation
Referents:
• Mathematics
• Science
Science
Teaching Faculty
Science
Content
Specialists
Science
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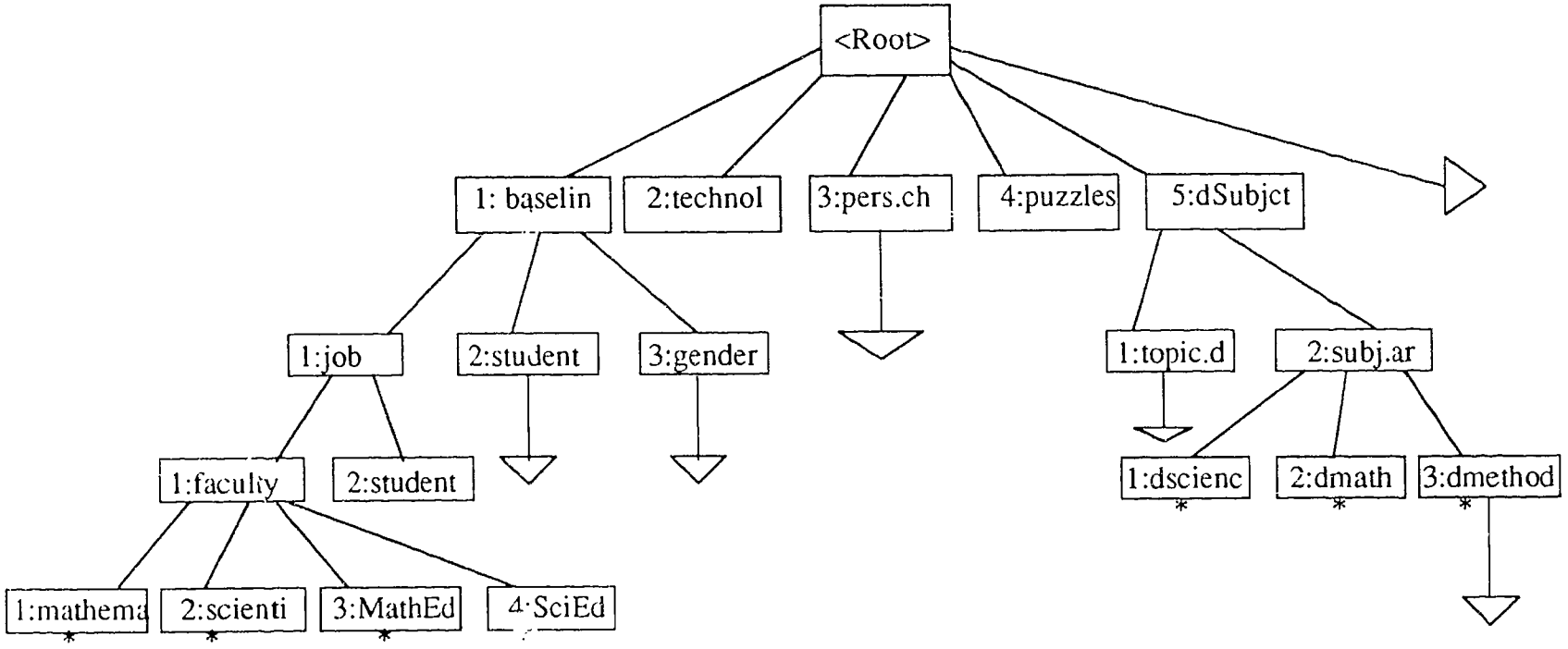
Specialists
Conversation
Referents:
• Science
• Mathematics

Figure 2 Caption

Figure 2. Tree index analysis of teaching faculty discourse as conducted by the software program NUD.IST.



Legend
baselin - baseline data about individual interviewed
job - data relevant to interviewee's job description
faculty - interviewee is a faculty member
mathema - interviewee is a mathematician, but doesn't fit "MathEd" definition
scienti - interviewee is a scientist, but doesn't fit "SciEd" definition
MathEd - interviewee teaches at least one math methods course
SciEd - interviewee teaches at least one science methods course
dSubjct - discussions of specific subject area
topic.d - topic discussed (i.e. what is said about subject area)
subj.ar - subject area discussed
dscience - science is discussed
dmath - mathematics is discussed
dmethod - teaching methods is discussed
↓ - there are (undisplayed) subnodes attached to this node
* - the node above was used in generating data for this report

Figure 3 Caption

Figure 3. Science Teaching Faculty's Collaborative Talk About Science

Conversation Start: Shared Understanding Between Scientist and Science Educator Discourse Communities

Referent: Mathematics is a tool (Speaker: Science Educator)

Conversation Catalyst: Understanding In the Scientist Speech Community Not Expressed in the Science Educator's Discourse Community

Referent: Mathematics is more than a tool (Speaker: Chemist)

Collaborative Conversation Development: Emergence of New Understandings in Both Scientist and Science Educator's Speech Communities Brought About By Collaboration

Referent: Mathematics is characterized by its intrinsic logic and beauty (Speaker: Biologist)

Referent: To truly understand mathematics, you need to be informed by a mathematician (Speaker: Geologist)

Conversation Termination: Controversial knowledge claim introduced at the end of the collaborative conversation for members of both the scientist and the science educator's speech communities to consider

Referent: Mathematics does not need science as a discipline (but science does need mathematics as a discipline) (Speaker: Biologist)