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Incompatible Goals: Narratives of Graduate Women in the Mathematics Pipeline

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Despite 2 decades of research and attention directed at enhancing their participation, the number of women earning a PhD in science and mathematics remains low. This article presents the results of an interpretive study of the educational and career paths of female students who have successfully completed a bachelor's or master's degree in mathematics and have chosen to leave the mathematics/science pipeline to research scientist in order to pursue a doctorate in education. The women's narratives portray the difference between their views of themselves and the nature of their chosen discipline. The emergent themes are examined against the conceptual framework of women's participation in the mathematics/science pipeline and women and their relationship to mathematics.

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> *Interviewer*: What did it mean to be a mathematician?
> *Terry*: I think that, for all of these people, it was their life.

The supply, quality, and composition of the U. S. talent pool in scientific and mathematic fields have been the subject of concern and discussion over the past decade (Berryman, 1983; Birke, 1986; Chipman & Thomas, 1987; Hilton & Lee, 1988; Lane, 1990; Maple & Stage, 1991; Oakes, 1990; Rossiter, 1982; Ware & Lee, 1988; Widnall, 1988). [1] And while these concerns are not new (Rossiter, 1978), several factors have contributed to the present intensity of interest. Increasing shifts toward science and technology in the nation's economic base coupled with declines in the college-age population have created concerns about the numbers of mathematicians and scientists (Lane,1990; National Science Foundation, 1987). Additionally, women have been attending college in increasing numbers in the past 2 decades, but they have been historically underrepresented among scientists and mathematicians (Hilton & Lee, 1988).

Women now earn approximately 35% of the doctorates awarded in the United States, most in the social sciences (Touchton & Davis, 1991). The number of women preparing for careers in the hard sciences, particularly academic careers, remains low (Widnall, 1988) with relatively few women making the transition from graduate student to faculty at research-oriented universities (Etaugh, 1984; McMillan, 1986). Participation of established women scientists is considered vital for the continued progress of women scientists in academia (Dresselhaus, 1984). Senior women setting an example of excellence in research, teaching, and service provide a powerful effect as role models, counselors, and advocates for students and for junior women faculty (Dresselhaus, 1984; Perucci, 1984).

The number of women choosing to major in mathematic and scientific fields has increased significantly since 1970 (Lane, 1990; Ware & Lee, 1988). However, evidence exists that equally prepared women defect from mathematics and science at a higher rate than men, particularly in the early years of their undergraduate careers (Oakes, 1990). In 1991–1992, women earned 41% of bachelor's degrees, 38% of master's degrees, and 21% of doctoral degrees in mathematics ("Earned Degrees," 1994). By contrast, women earned nearly half of the mathematic education doctoral degrees in 1990 (*Digest of Educational Statistics*, 1992). But, of new doctorates in mathematics, women were only 24% of the new-hires in academic departments (31% of new-hires in research institutes) (Annual AMS-IMS-MAA Survey, 1993)

Many authors have used the term *mathematics/science pipeline* to describe the process as students' continued participation in mathematics, science, or engineering; achievement in those subjects; and the development of attitudes and interests that lead them to continue to pursue those subjects (Berryman, 1983; Chipman & Thomas, 1987; Maple & Stage, 1991, Oakes, 1990). A limited amount of research exists that attempts to understand factors related to women's success in the pipeline (Cole, 1979; Hackett, 1985; Stage

& Kloosterman, 1995). While a need exists for research on the experience of women at all levels in the science and mathematics pipeline, this study is limited to the background and experiences of seven female students who successfully completed a bachelor's degree and chose to leave the mathematics and science pipeline to research scientist in order to pursue a doctorate in a social science field. Five of the seven changed tracks to mathematics education.

Conceptual Framework

Two areas of research and theory have informed this study: (a) women's professional and educational development and (b) perspectives on mathematics as a subject. Central to this analysis is a focus on women's professional development within the context of academic departments within research universities.

Some literature suggests that women in general differ from men in their orientations to research, teaching, and service. Olsen, Maple, and Stage (1995) employed structural equations modeling to explore relationships between women and minority faculty's professional role interests and satisfactions, the fit of these with institutional values and satisfactions, and overall job satisfaction at a major research university. The women, in general, appeared to share with their male counterparts values emphasizing research scholarship and publication. A borderline effect suggested that women spend slightly less time on research than other faculty (perhaps a product of external constraints).

> It is important to note that women, like their white male colleagues, tend to define themselves professionally in terms of their research, derive as much intrinsic reward from their academic work, and are as satisfied with their research activities. There was nothing in the data to indicate that female faculty apportion significantly more time or demonstrate greater interest than white male faculty in teaching or service. (Olsen, Maple, & Stage, 1995, p. 283)

The study included interviews and, as an interesting aside, women talked of a sense of disconnectedness from their academic departments. Often, they were not included in lunch groups or after-work drinks or other important venues for communication.

Some authors have focused on socialization of graduate students within academic departments as key to retaining students (Louis & Turner, 1991) as well as mentoring future faculty (Kirk & Todd-Mancillas, 1991). Socialization could be viewed as a way of actively incorporating graduate students into the culture of a department (Van Maanen, 1984). Some researchers have found that women in particular are more sensitive to support features of their graduate school environments (Hartnett, 1981; Stansbury, 1986) and they rated those support features higher when they had female major professors

(Schroeder & Mynatt, 1993). Understanding more about such attempts at socialization might prove useful to those hoping to improve the persistence of women in science and mathematics fields.

The ways in which people's conception of science and mathematics is entwined with conceptions of masculinity have also been the subject of extensive academic discussion. Scholars have noted that women's judgment (Gilligan, 1982) and orientation to work (Harding, 1989; Keller, 1984) differ from those of men. Keller (1984) describes science as *genderized* (characterized by the objectification of the subject rather than as a field that celebrates a union between mind and nature. Much scientific work is conducted in effort to impose rules or answers. Results incompatible with those rules are viewed as errors rather than attended to as valid pieces of information. She argues instead for attendance to the detail and subtle nuances of an organism (in the life sciences). Such appreciation of difference is sometimes described as more characteristic of women than men. These aspects of genderization contribute to a conception of science as a field more suited to men than to women. Harding (1989) argues that women's normative ways of "seeing" and "knowing" should not be considered less desirable or effective as an intellectual stance. Possibly, similar distinctions can be made in mathematics in approaches to problem solving by women and by men.

Finally, Salner (1985) suggests that women, as a result of their psychological development, are less likely than men to believe in the superiority of empirical science and its methodology and are more comfortable with, or possibly in need of, intellectual tools that do not require them to dissemble their sense of identity from its natural or social context. Women in graduate school could be disadvantaged by traditional emphases on empirical science with its dominant ideology.

> By defining science and scholarship as synonymous with traditional empirical practice, we limit everyone, men as well as women, to methodological forms that were serviceable in the physical sciences of the 19th and early 20th centuries but are now demonstrably inadequate on philosophical grounds. (Salner, 1985, p. 56)

Salner goes on to urge that educational organizations move from the mere acceptance of women in their midsts to acceptance of the feminine as an abstract but essential ingredient in the development of knowledge.

In sum, these studies suggest that changes in the assumptions and paradigms that guide scientific inquiry and recognition of the inextricable social character of the sciences would provide a valuable expansion to the set of resources employed in the study of science (Harding, 1989). Consideration of perspectives on science provides yet another framework from which to probe for a more complete understanding of the experience of women scientists in the culture of orientation. Widnall (1988) pointed out

a continuing lack of documentation on the environment in graduate school and its effect on degree completion rates in science and mathematics. In the absence of such research, researchers have only a limited understanding about the ways in which individual potential is encouraged and developed or fails to reach fruition.

This study had three objectives: (a) to examine and describe factors relating to respondents' participation in the mathematics pipeline, (b) to examine and describe perceptions and experiences of female students and their relationship to the subject of mathematics, and (c) to examine and describe the relationship between women's perceptions of mathematics and perceptions of themselves within that discipline.

Methods

While a conceptual framework guided interpretation of the responses, we wanted respondents to define their own experiences. The methods chosen to collect (open-ended interview, see Appendix A) and analyze the data followed the narrative approach (Bruner, 1987; Eisner, 1991). The primary sources of data were seven American-born female doctoral students at a large midwestern research university. (See Appendix B for profiles of the respondents.)

In each case, the respondents had successfully completed a bachelor's degree in mathematics. All were enrolled in doctoral programs; their graduate histories varied, however. One woman had entered a graduate program in psychometrics and was currently working on an educational psychology degree. A second had attempted to enroll in a master's program in mathematics and, despite her qualifications, was diverted to a master's in teaching; currently, she was enrolled in the doctoral program in mathematics education. One woman entered a doctoral program in mathematics after earning her bachelor's degree, but, after a year, she switched to the doctoral program in mathematics education. Three women enrolled for from 1–3 semesters of master's level work in mathematics before changing majors and earning a master's in mathematics teaching—one of these was enrolled in curriculum and instruction and the other two were enrolled in mathematics education for their doctoral work. Finally, one woman earned a master's degree in mathematics and, after more than a year in the PhD program in mathematics, ultimately switched to the doctoral program in mathematics education.

The women's graduate experiences in mathematics occurred at a variety institutions, although four of them enrolled in graduate mathematics course work at their current institution before changing career paths to pursue a PhD or an EdD in education. Because students were asked to recall past experiences ranging from 2–15 years ago, extensive time and follow-up were built into the study. Each respondent participated in two interviews each averaging approximately 2 hours.[2] Questions from the first interview

were repeated in the second interview in case the respondent later recalled an experience or perception that was not discussed the first time.

Research questions were probed in a flexible manner using semistructured interviews (Merriam, 1988) following a protocol developed by the researchers (Appendix A). Each respondent also completed time lines of significant events for their education, work, and personal lives. In addition to prolonged engagement, member checking and peer debriefing were employed to ensure validity of the results (Lincoln & Guba, 1985; Miles & Huberman, 1984). The semistructured interviews continued until it was mutually agreed that further discussion would provide little new information. The interviewer took notes and also tape-recorded and transcribed the interviews. Pseudonyms were used and results of the study were provided to all respondents.[3] The first author is a woman who left the mathematics/science pipeline after earning a master's degree in mathematics. The second author is a researcher with particular interest in the socialization and enculturation of graduates and students in the professions. Some assumptions of the researchers that could possibly influence the interpretation of the study included: (a) It is desirable to have women in the mathematics pipeline as role models; (b) women who leave the pipeline leave a career goal unfulfilled; (c) women's lower levels of participation lead to economic differences in salaries earned, and, (d) through understanding, researchers may be able to help more students, both male and female, stay in the pipeline.

Results

Narratives of the respondents were grouped around emergent themes used to represent women's career paths. Themes were grouped generally according to whether the themes represented (a) participation in the pipeline, (b) the women's relationships to the subject of mathematics, and (c) the differences between themselves and the culture of mathematics. These women's voices describe their own participation in the mathematics/science pipeline, their relationships to the subject of mathematics, and their growing awareness of difference between themselves and mathematics as a career. Narratives of their experiences provided examples for the themes.

Participation in the Mathematics/Science Pipeline

The early educational and family background of each respondent and how these lead to their initial choice of mathematics as a major was not the primary focus of this article. Page limitations preclude extensive discussion here. Limited background information is provided in the profiles of the respondents (Appendix B). Briefly, many women talked about the importance of a parent in their initial choice of major. One respondent's mother had majored in mathematics (Appendix B: Claudia); a second respondent's father had devoted time to solving mathematical puzzles with her (Appendix B: Mary); additionally, her father had insisted that she enroll in calculus

when guidance counselors had deemed it unnecessary (Appendix B: Mary). Other women discussed the importance of mentoring or examples set by faculty in their high schools (Appendix B: Jennifer, Ellen, Terry). These examples were contrasted with stories of high school teachers who made sexist remarks that left students feeling inadequate in mathematics (Appendix B: Mary) but whose negative influences were eventually overcome.

Not all the women were mentored into mathematics. Pat's entry into the math/science pipeline was for unusual reasons; she double-majored in mathematics and psychology and felt as if she had something to prove:

> *Pat*: Well...to compare myself with my husband, because we are so similar in a lot of ways; yet, he never valued psychology, he always valued the sciences and math. And, in a lot of ways, I think he valued what I was doing as an undergraduate highly because I was a math major. We were kind of equal in his eyes.
>
> *Interviewer*: Because that represented...?
>
> *Pat*: The brilliant and scientific mind...the man. It's always the men who are thought of this way: It's like the macho of the intellectual world, you know, of academia. I think that's a big part of why I chose it. I didn't care that much, but I chose it because I wanted to show that I was just as sharp as any man. So, I do think that—being female—made me look at that as a male thing and to value it for that reason. But, I've always valued relationships very highly, and I think that's very female....I still needed first to prove...
>
> *Interviewer*: You felt that strongly?...
>
> *Pat*: Yeah. This was my choice. I could do your macho thing over there, but who needs it. I wanted to be able to do that. That's a big part of why I did it....

Concerning their college years, several respondents related stories of mentors who provided guidance, encouragement, and friendship. Those mentors were more often male than female (unsurprising given the preponderance of men among mathematics faculty).

> *Terry*: The professor that I had—it was a small college, a two year college, and we only had one professor in math that was full time. He was really personable and real nice...this was in college my first year. Several times I talked to him and he really encouraged me to go on and take Calculus II, which happened, at that time—at this college—the month of January was...like you took one class, you went every day—it was called "interterm." But, some people went off campus to do other things, because the semester didn't start until February. So the whole month of January I took only one course; and, if I was going to take Calculus II, I had to take it then, because that was the only time it was offered. It sort of interfered with my basketball, because they were going on a trip and I couldn't go. But I'd made the decision.

Terry felt that her choice, to forego her basketball team's field trip in

order to take Calculus II, marked her choice of mathematics as a major. While male mentors, like Terry's, predominated, for one woman, the presence of a female mentor was of particular importance.

> *Kate*: In that department, there was only one woman PhD mathematician....There were two with master's degrees, out of seventeen; so, we did not have a phenomenal amount of role models there. And one woman did an independent study with me for abstract algebra...
>
> *Interviewer*: Was this the one woman who was a Ph.D. faculty member?
>
> *Kate*: Yes, she was a PhD faculty member, before my bachelor's degree. She asked if I wanted to do an independent study with her for a second semester of algebra....She has been a tremendous support all of the way through. She said to me at one point, "Algebra is where people decide if they are going to be math majors or not." This is the make it or break it.

Interestingly enough, at the undergraduate level, most of the women had no idea what they might do with their college degree in mathematics other than teach or become an actuary (as undergraduates, none of them actually knew what an actuary did). The descriptions they provided conjured the image of drifting; they took courses full of problems that, to them, resembled games or puzzles, but they saw little relationship to the real world in their solutions. Additionally, they seemed to have few options for obtaining career advice.

> *Jennifer*: I didn't know. I didn't know what you do with a math degree....As you grow up, the only people you see in math are math teachers. So, you have a real good idea of what a math teacher does. But beyond that, unless you have personal experience...you don't know what they do with math degrees. I didn't at the time...people said, "Actuaries work for an insurance company." That sounded really dull to me, and I wasn't really interested in that. Then, as my college career went on, and I became...I kind of...just pulled into education, I guess, at that point. Because, I was trained in math, and I really didn't think that I wanted to go be an actuary, so, I decided, "Let's give teaching a shot." So, I was pulled...or sucked into it, as my college career went on. But when I went into it initially, I was not planning on being a teacher....
>
> *Interviewer*: Okay. Who did you talk to? You know, you're in college, and you're thinking about what you could do with your math degree. Who did you talk to about your possible career options? Or about your major? Or what to do?
>
> *Jennifer*: Well, I talked to my roommate, I'm sure, and I talked to my folks. But I don't recall ever going to a professor and talking to them.
>
> *Interviewer*: Why not?
>
> *Jennifer*: I have no idea...I didn't go to office hours much; I didn't

> go to professors for help much. When I needed help, I'd go to my roommate. And if she couldn't give it to me, then we would go to office hours together; but we rarely did office hours.

As suggested above with Jennifer's roommate, peers often played important roles in students' described experiences as mathematics majors. For some students, however, peers, particularly fellow mathematics majors, offered little in the way of support, and these women found themselves forming primary friendships outside their mathematics peers.

> *Interviewer*: How about when you were a math major; did you know other math students very well? Did you have many relationships with those students?
>
> *Claudia*: I didn't especially, and I've tried, recently, to understand why....But I did not have good friends in my dorm who majored in math, so we didn't have study sessions which seems to me a great loss now. I did discuss the philosophy of religion with friends, but there were just no other math majors nearby. I was very isolated....There was a math club, at one point; and I ended up being president of it, but there wasn't much to do. But, it was the sense that we needed something to draw people together; but it didn't, it didn't really do that. It was very hard for students to figure out what would be interesting. I think that it needed a little more influence from the faculty...

Possibly, when lack of human connections occurred, with few other women to share experiences, women felt particularly isolated.

Relationship to the Subject of Mathematics

Respondents described their initial relationships to the subject of mathematics in sometimes playful and often fond terms. Some described class subject matter and assignments as a series of puzzles. Their satisfaction with the solutions of mathematics' increasingly difficult puzzles attracted them.

> *Interviewer*: Did you like it because you could do it?
>
> *Terry*: No, I liked it because it made me think, and there were a lot of things in high school that didn't take too much thought for me to do. And, sometimes, math didn't either; but I liked it because it was something that I could sit down and...sometimes it would take a long time to do a problem, especially when I got into college. We had, sometimes, take-home tests. I remember when I was taking Differential Equations, all of our tests were take-home, and we'd have a week to do them. And I'd work on these problems, and work, and work, and work...I had a roommate, but she wasn't a math major, but I would, sometimes, talk in my sleep. She said I'd always be talking when...she knew when I had a test and I'd work late...then I'd be talking. Sometimes I'd wake up in the night and I'd think of it. "This

> is how it's supposed to be done," and I'd write it down. So I found that really challenging, and I liked it...So I decided that...to be a math major.

In general, students felt that they knew what was expected of them as undergraduate mathematics students. Performance standards generally were clear-cut and well-defined.

> *Interviewer*: Did you know what...things indicated a good student?
>
> *Claudia:* I think so. I mean, at that point in math, it was pretty clear what's acceptable—proofs. The question of what is a proof, and at what level are we going to do something came a bit farther on—maybe in the senior year. But, most of college math is still critical; you knew when you had it. So, I think, I knew what was expected...I think it probably just sprang from the professor's lecture. You assumed this is what your response is going to be...this point of degree of accuracy, this control of material, this competence...

For some women, however, the same characteristics that drew them to mathematics as a game began to turn them away. The increasingly narrow focus of the upper levels of mathematics became unsatisfying. Pat described a transition from mathematics as a creative activity to something more practical that was, for her, both limiting and disappointing.

> *Pat*: I think that I loved it because it was my chance to prove myself. It was another big game. It didn't have anything to do with putting the whole real world together, or putting rockets on the moon, and all of that...it was highly creative! It was more like the way I feel when...I put together a gorgeous dance. I danced all of my life...something beautiful worked out, and I did it...and nobody else did. But...abstract algebra, and...topology, and...advanced calculus,...and were all geared toward...what math really was, what could it do in the real world...I realized...I was a math major, and I didn't really care about what I could do with it.

In contrast, however, most described a growing frustration with the seeming lack of connection of mathematics with the world surrounding them. Mathematics began to seem an endless series of puzzles that could be solved if enough time or effort was invested. Sometimes solving problems did not even seem to lead to the learning of mathematics but merely represented the results of that investment of extensive time and effort. Solutions bore little relationship to others' learning of mathematics, social issues, or the people in their own lives other than professors or fellow mathematics students.

> *Mary*: Like I'd said before, this need to sort of better society, that if I wanted to spend 40 hours a week in a career, that I not only want to enjoy it myself, I want to feel like I'm helping society be a better

> place to live. And pure mathematics, to me, I don't see how it's going to help the world be a better place...So it's hard for me to get motivated just to think that I'm doing this because it's fun. I don't know. It seems selfish to me, just to sit in an office and be a mathematician because I think it's fun, but it's not like it would help anybody else....
>
> Topology is useless. Topology is not used in the real world. But see, ironically, I enjoy the field of topology. I enjoy studying topology as this part-time hobby thing. I love...I took a 400-level topology course here at (university) and I just loved it. It was just the right amount of intensity. That was perfect for me. So it is fun, but to do it all the time...it sort of is like a crossword puzzle. No one would begrudge someone spending half an hour on a crossword puzzle every night because it's fun. But if someone did crossword puzzles 30 hours or 40 hours a week, you'd say, "Is something wrong with you? There's more to life than doing crossword puzzles." That's sort of how I see mathematics.
>
> *Interviewer.* That's an interesting analogy.

While students' views of classroom expectations were generally not a source of dissatisfaction or disassociation, aspects of expectations regarding the mathematics culture were. In general, responses to the question "What did it mean to be a mathematician?" were negative— especially after students became involved in graduate work.

> *Jennifer.* Well, the idea of getting a PhD in mathematics—and this was a joke in the department...among the graduate students in the department, getting your PhD in mathematics means spending your life in a closet with a light and a desk'...which is another way of saying...*isolation.*

In answer to the question, portraits of isolation and lack of social interaction were frequently depicted. All respondents spoke of expectations on the part of faculty about doctoral study in mathematics that involved extensive time commitments and few interests outside the mathematics department.

Difference Between Themselves and the Culture of the Discipline

During the graduate experience in mathematics at the master's or the doctoral level, all these women were somehow convinced that a PhD in mathematics was not what they wanted. One woman, because she was a returning student, was required to have her professors report regularly to her advisor on her class progress; she quickly proved herself capable of graduate work (Appendix B: Jennifer). A second respondent, as a very young woman just out of her undergraduate degree, applied for a graduate degree program in mathematics. She was telephoned by the department chair's wife and asked if she might prefer a degree in mathematics education where she could have a fellowship rather than one in mathematics where she would be required to teach. She complied, but now wonders whether she would

have made that decision today (Appendix B: Claudia). For Ellen, her first graduate mathematics course was the last math course she ever took. She described her return to graduate school as a part-time student:

> *Ellen*: Yes. So I applied for, and got, an NSF grant...to (technical institute). It was Saturday courses, while I was teaching. And I really loved getting back into math again, but this time it was a whole different experience...To this professor, we were nonentities. We were sitting out there, and this is what he did. He was the major presenter. He really did, and any questions you had, anything that was going on, you talked to the "AI." A little flunkey. I don't mean that in a derogatory way, but I think that's how he treated him. "I will do the major, what has to be presented, and then you take care of all the little things that slide by." And so it was like, "I'm not sure I like this."
>
> *Interviewer*: Because you didn't see it as people-oriented?
>
> *Ellen*: They spent their time in their little office all by themselves working out theory. And in order to have the time and the money to do this, they appeared before a class for as short a time as possible and presented something to them. They didn't even discuss, they presented, because there was really no discussion. We held all questions until he finished, and then the AI took over. And he would leave...
>
> What I felt it was, was the mathematician created something in basically his own space. I did not get the feeling at all that women had a place in this world...I did not fit...part of me says, "I'm going to prove to you that I do belong." But it was always like proving like I was going to ace this exam or this course just to show you that I can do it. It was very much a spirit of competitiveness, you have to prove yourself, and...I aced the course, but it was a real empty feeling basically. It was like I'm not sure the professor—he never saw the grades. The AI figured everything out. We knew that. And it was at that point that I...decided I don't belong in this field.

Other students did not have such strong initial negative reactions. For them, turning away from mathematics came more gradually and seemed almost the accumulation of disappointments and dissatisfactions. Two students talked about competitiveness among students; at least three talked about the very small number of graduate students who passed qualifying exams. Others knew students who talked of checking out books on class topics from the library and keeping them all semester so that classmates could not use them. Kate discusses competitiveness:

> *Kate*: I didn't feel like I wanted this bad enough to put up with that. With what I considered to be non-support and the constant, the constant having to go after things myself. I didn't feel like I wanted to do that anymore. I didn't want to study math so bad that I was willing to put up with everything else.

Three women spoke of an apparent incompatibility between the life of a doctoral student in mathematics or the life of a mathematician and personal

goals that might have included marriage, or a family, or other aspects of a life outside mathematics. Mary contrasts her own priorities with those of a fellow mathematics doctoral student who had resigned himself to 3 years of absence from his young family while completing his degree.

> *Mary*: If, for whatever reason, I thought that my marriage was suffering because of this Ph.D. program, I would quit right now. I never thought...I would say that. I have 4 more classes left before my dissertation. I never thought that I would say, 'If I had to make a decision between my husband and my child, or this Ph.D., I'll give up. Just like that. [Snaps fingers.] It's sort of scary. But I feel very strongly about that...in wrestling with having to leave the math department...in talking with this graduate student who said, "I'm not going to see my kids for 3 years, my wife is doing all the raising of the kids." That caused me to think what kind of parent do I want to be? How important is this to me? Do I want to be like that? And sort of seeing bad marriages and bad relationships because people have been so preoccupied with their career, their degree, that I'm becoming stronger, saying, "I don't want to be like that." Because I see how bad this is. I think that's terrible, to have a picture of your kids on your desk and that's all...

If the topic had not already arisen, each respondent, at the close of the second interview, was asked to reflect on the relationship of being a woman and their experiences. Some interesting comments resulted. Jennifer believed that advice for men and women entering graduate work in mathematics would be the same. She also believed that not having women faculty was a critical deficit in her personal experience.

> *Jennifer*: Oh, I don't think that I would have a different message for women than I would have for men...it's a problem not having more female faculty...I think that for undergraduates...women have more difficulty establishing a relationship with a man, they are more uncomfortable with a man than they would be with a woman faculty. That's why, frequently, they don't want to go to office hours, because they are just kind of leery of this man....Some male faculty portray themselves very professionally, and there would be no problem there; but there are others who are more friendly. If you have a very friendly—even if he doesn't have anything in mind, he's just a friendly person. And you have a 19 year old woman...it doesn't matter if he says something—or does something—it's just the fact that she is a little leery...I think it is a problem, by-and-large, faculties are predominantly male; and it makes it a little more difficult for the female then to go and talk to him, depending on how he sets himself up to them.

And Mary's comments:

> *Mary*: You never asked me "Do I think men are better at math than women?" That's a question that I have been wrestling with.

Interviewer: Well, what do you think?

Mary: I think when I applied to graduate school I would have easily answered,"Women and men can do math the same." And now, believe it or not, I'm actually starting to question that...I think it has to do with sort of this preference kind of thing: How could a woman focus her life on this abstract stuff, not dealing with people? I see women as very personal, people-oriented. And I know that's very sexist, but the women...I think that society has nurtured men to go off in corners and play with their erector sets and solve problems and be independent thinkers and that kind of thing. And women have been taught to talk up a storm and be very social and care about other people...That we are thrown into graduate school and asked to sort of think like a man, be like a man...And I don't think that it has to be that way either. I think math in classes, why can't you have more group problems? I took a math class where the professor actually assigned us to work in groups...I loved it! I took the sequel too. I told the professor, "This is the only elective math class I have ever taken in my life."...Math does not have to be the way it is, where you go off and just do it by yourself. So—but, because men are teaching it and men are in the classes, it's going to stay that way. It's not going to be a social kind of thing. My husband hates working in a group....And if you have men like him, he's going to go off and probably be a professor someday, and he's going to structure his classes where everybody goes off by themselves and they do it.

More than one student who had attended the same graduate institution reported that generally the faculty never bothered to learn the names of the graduate students in their classes; until they passed their qualifying exams, students were not considered seriously. Another student thought that the faculty did not waste energy on any student not considered serious. Kate described the isolation of her graduate experience and attempts she and other doctoral students made to make the experience more positive for other women.

Kate: When I first came, of course, I didn't know anybody; so, there is no network...and the math faculty are not very good at creating one for you...and theirs is a very large department....But, I think that not having a support system....Maybe if...they had sufficient women in that department to find two or three key women friends, that might help, but I don't know. Support systems take a long time. You can't just walk into one. In the meantime, you can feel pretty scared and pretty isolated when you are doing it. Now we did...I'd say, at the end, there were two or three of us women grad students who tried to seek out the women, incoming, especially the incoming olders, over 25, or the incoming who were coming from these little bitsy colleges. We'd take them under our wing and say, "Let's all have lunch together, one day a week," or, "Let's all go out to dinner, or see a movie"...

Here, you can fall through the cracks so fast it's not even funny, and nobody will even know that you fell through. Nobody will ever

> know! You could...commit suicide, and nobody would know it for days...I think it's a cold place because they do not know who you are and you don't know who they are. Establishing, or getting to know each other, is not a simple process. I don't know that...anyone can adequately prepare you for that when you come. They could make an attempt to be a little more inviting and a little warmer...
>
> Do you know about...the math department's "teas"?...Walk into a room with sixty men in it, and they're all standing there talking about mathematics, so it's very warm....There will be two or three of them who might try to acknowledge your presence, and most of them continue on in their little conversations...talking about their research, and you know nothing about it...I just didn't know what to do; so I took the path of least resistance, and left.

Kate goes on to say that, with the establishment of a support group, things began to get better. However, by that time, she had already psychologically withdrawn from the department and was working toward transfering into mathematics education.

Discussion

This study focused on a narrow group of students and their experiences in a particular discipline; one might argue that perhaps the men in these mathematics classes faced the same obstacles that these women faced but were more adept at overcoming them. Similarly, for women who remain in the pipeline, perhaps they too are able to cope better with the culture and the pressures of graduate mathematics study. Nevertheless, it is hoped that through this study educators will learn of ways to encourage more students, both male and female, to remain in the mathematics pipeline.

Respondents to this study consisted only of women who, after their experiences in mathematics departments, enrolled in doctoral study in the school of education and voluntarily participated in the study. Possibly, the contrast to their present academic departments created distortions of their memories of mathematics. Women who left graduate mathematics and moved to other fields of study or left academe altogether might have different perspectives.

Additionally, those interviewed were all White, middle- or upper-middle-class Americans. It is likely that their observations and experiences differed from those of ethnic minority students, first-generation college attenders, and international students. Finally, the interviews required students to recall experiences from the past, ranging from 2–15 years past, for their graduate experiences. Possibly, some recollections were inaccurate or exaggerated—that point should be kept in mind when reviewing these results. Nevertheless, themes generated in this research should prove useful for those who seek to learn more about participation in the mathematics pipeline.

Two basic concepts described in the literature review were used to organize themes described in women's narratives: conceptualizations of the

subject of mathematics and respondents' relationships to mathematics as a discipline. This framework, as it emerged, takes the reader on an almost thematically ordered regression of self from the discipline of choice.

Initially, most of the women described an interest and aptitude in mathematics that began in early childhood and was often fostered by parents and/or interested teachers. Most could name a particular person or persons responsible for their consideration of a mathematics major. Without this individual mentoring, they would not have made it into the pipeline. Interestingly, such mentoring by family members was an important common element in the lives of great women mathematicians (Fowler, 1986). For all respondents, that initial interest and aptitude continued so that undergraduate college mathematics courses were described variously as challenging, similar to puzzle solving, fun, and creative. All the women, however, related negative experiences regarding their undergraduate work in mathematics. Some negative experiences had to do with peer relationships, such as competitiveness or failure to be taken seriously by male classmates. Others described isolation of the subject from other areas of interest and from the realities of everyday life. In many cases, faculty relationships were less than ideal. A few women spoke of their reluctance to visit male faculty during office hours and of relying only on peers for advice. These statements, along with the narratives of some of the respondents, support Schroeder and Mynatt's (1993) finding that women with female major professors might fare better in their graduate programs. Although most of these female students had begun the major not wanting to teach, none had a clear view of what else one might do with mathematics. Mathematics faculty seemed unable to help them with career decisions.

In reflecting on their entry into graduate study, each respondent had at least one memorable negative experience to relate that stood out for them in their decision to leave mathematics or to choose education for their graduate work. Some respondents reported being treated differently from male applicants. On entering graduate studies, one was directed into a mathematics education program, although she was qualified for the mathematics program. More than half described graduate courses where faculty did not bother to learn students' names and kept themselves as distant as possible from students. Most narratives described enjoyment of early experiences involving group efforts in mathematics and fondly depicted experiences with students and teachers working cooperatively on problems. But by the time these women reached graduate study, only one described a class where group effort was expected and encouraged by the professor. Additionally, the nature of the mathematician—the generalizations or stereotypes the women had created from their impressions and experiences—did not match their early perceptions in other ways.

Several of the respondents spoke of a perceived conflict between mathematics as a profession and other roles—such as, parent, community member, and significant other—that influenced their decision to leave the

mathematics department. This process of decision making within the context of personal relationships fits patterns described by Gilligan (1982) and others.[4] These negative experiences, combined with the difficulties and stresses of graduate course work, were sufficient to steer students from their goals of attaining graduate degrees in mathematics.

The possibility exists that some of the respondents did not possess the intellectual capability or the stamina to complete a PhD in mathematics. Two of them spoke particularly of difficulties with the material and of inordinate amounts of time spent on classwork. However, other narratives described highly successful classroom experiences where the women were often at the top of their respective classes. Nevertheless, they decided that mathematics, with its seemingly total absorption of one's life, was not for them.

Recommendations

Participation of all demographic groups in mathematics, science, and engineering study is declining precipitously. This article focused only on women in the mathematics/science pipeline. Possibly, these narratives would resemble those of others whose participation is needed in the hard science fields: ethnic minority students of both genders and men who have left these fields. It is hoped that the results of this study might be used to retain more diverse students in mathematics, particularly, as well as the other sciences.

At the onset of the study, we described assumptions that helped formulate the study. Some of these assumptions were reinforced through the narratives and form the basis for recommendations.

It is desirable to have women in the mathematics pipeline as role models. This study echoed suggestions of others that mentors and role models are important particularly at the college level in laboratories and classrooms. Schroeder and Mynatt (1993) reported that women with female major professors gave higher ratings in general to the quality of interactions with their professors and to the professors' concern for their welfare. Undoubtedly, having more women in classrooms would broaden students' images of mathematicians' lifestyles, temperaments, and intellectual approaches to their discipline.

In addition, however, women in this study suggested that men sometimes played key functions in their development in the mathematics pipeline. Indeed, the absence, in the immediate future, of significant numbers of women in mathematics departments means men must be relied on for mentoring and even role modeling. Olsen, Maple, and Stage (1995) explored the relationships between professional role interests and satisfactions—satisfactions with institutional values and expectations, and overall job satisfaction of faculty at a major research university. In some areas where differences were expected, women were similar to men—particularly, in interest in research as opposed to teaching and service. Perhaps, one might posit, the interests, learning styles, and temperaments of women who persist in the hard science fields are similar to those of the men currently occupying

positions in those fields. The narratives related here prompt one to wonder whether single-minded dedication and absolute sacrifice are essential to model (by faculty) or to emulate (by graduate students). Conceivably, in the future, as men's and women's social roles evolve, male faculty will also begin to demonstrate lifestyles and temperaments that are broader than those that currently exist in mathematics departments.

While echoing others' recommendations regarding the importance of role models, we acknowledge a shortage that often prevents a critical mass of female faculty from being hired in mathematics. In such instances, some needs could be met by inviting female mathematicians and scientists to visit as scholars in residence or as guest lecturers. During the course of those visits, meetings specifically for female graduate students could be scheduled to talk specifically about professional development and lifestyle issues.

Women who leave the pipeline leave a career goal unfulfilled. The women reported a variety of reactions to their changes in career goals. Some reported finding, through their most recent graduate studies in education, vocations that more closely matched their own life values. Not one of the women was without regret at the inablility to complete what she had initially aspired to. One wonders whether a different experience might have left them more fulfilled, one in which some were successful in their mathematics studies, went on to faculty positions, and were able to conduct their faculty lives in congruence with their espoused life values.

One striking similarity among the women was their lack of information (as undergraduates and sometimes as graduates) about "what they could do with" a mathematics degree. This lack of information prompts one to wonder whether their career goals (as undergraduates) were realistic. Possibly, with information about available career options, these women might have seen possibilities for themselves in mathematics other than tenure tracks at research universities. Equally important, with better career counseling, perhaps some of the women in the sample would not have entered mathematics in the first place. Obviously, the women would need to receive this career information before they reached critical career decision points, prior to entering graduate study. Such counseling might ideally take place for college juniors who are mathematics majors; it could certainly occur on entry to graduate school.

Women's lower levels of participation lead to economic differences in salaries earned. This assumption was unexamined within the context of the study. The women were still completing doctoral study, as were most of their colleagues who had remained within mathematics education.[5] A follow-up study might be conducted to document whether or not this assumption was correct.

Through understanding, researchers may be able to help more students, both male and female, stay in the pipeline. In the absence of faculty and administrative action, graduate students would benefit from being more aware of the precariousness of their positions. As advised by another, a

student was told to look around in an initial class meeting and know that two out of three people in the room would not be there to complete the qualifying exam sequence. Support networks and study groups can be created by students who search for solutions, share information, and provide support in difficult times.

Faculty and administrators in mathematics could play a greater role in the establishment of peer support networks, as some respondents in this study attempted on their own. Another possible practice could be the admission of cohorts of students that would more naturally provide group support for students throughout their graduate study. Finally, simple measures such as prescribing the courses to be taken during the first year so that students have consistent contact with one another might prove useful.

Of course, the obvious advice for universities and colleges is that they make every effort to recruit and retain underrepresented faculty in the mathematics and sciences within their research ranks. In the meantime, mentoring networks could be established for underrepresented students that included tenured underrepresented faculty in all science and mathematics fields.

Maple (1994) reported descriptions of graduate experiences by women who were completing doctoral study in the hard sciences. In contrast with the narratives of women reported here, they expressed fewer problems with their relationship to science as a subject or the connection of science to the world around them. Did the women in Maple's study have differing, and possibly more realistic, views of the nature of study in the sciences? Perhaps the issues raised in the present article are characteristic of the specifically abstract nature of mathematics. Although most of the students in Maple's study were committed to teaching, their interest in research was often strong.

With the results of the present study might come defensive comments that these women self-selected themselves out of doctoral study in mathematics. However, evidence exists that the social climate and attitudes in general in mathemetics affect all female graduate students negatively. Like the respondents in this study, Maple's (1994) successful doctoral candidates reported being negatively affected by gender differences in styles of communication about the subject matter, tokenism, and stereotypes of women as less serious students than men. Further study might include both successful and unsuccessful students. Additionally, more detailed information, including narratives of people who are successful in their pursuit of hard science doctorates and research faculty positions, might be useful.

As we conducted this research, we sometimes doubted the wisdom of counseling women into study in the "hard sciences" without special preparation. From the narratives of this study, one sees that often enthusiastic, intelligent students were turned away from their favorite discipline—mathematics. The students' narratives provided suggestions that might prove useful to faculty and other professionals who are interested in promoting the success rates of diverse graduate students in mathematics.

Some people envision a world where people of all temperaments, learning styles, and viewpoints will hold faculty and research positions in all disciplines (Harding, 1992; Keller, 1984; Salner, 1985). In the Olsen, Maple, and Stage (1995) study, successful women resembled men. Perhaps in the future, successful mathematicians and scientists will be more representative of society in general.

APPENDIX A

Interview Protocol

1. You started out as an undergraduate in mathematics. What factors initially influenced your decision to study mathematics?
2. Were there some aspects of mathematics that especially attracted you or fascinated you?
3. What did you think studying mathematics would be like?
4. Was it like you thought it would be?
5. As an undergraduate, did you establish relationships with faculty and/or other students in your field?
6. What messages were conveyed about what it meant to be a mathematician? Could you tell me about the kinds of skills or attitudes that were valued or considered appropriate?
7. Who did you talk with about your major or your career options in mathematics?
8. What about lifestyle? Were there any messages conveyed about the kindof lifestyle a mathematician would have?
9. Were performance standards clear to you? Did you know what you needed to do to be considered a good student?
10. How did you know? Did you learn things through formal channels or was it primarily informal?
11. Did you feel that you "fit in" in mathematics? Was there anything that would have helped you to achieve a better sense of fit?
12. How did your experiences impact on commitment to a career in mathematics? Perceptions of mathematicians? Perceptions about career options?

(13. Do you think your perceptions about mathematics were influenced by the fact that you are a woman? Do you think that your experiences would have been different or that you would have perceived things differently if you had been a man?)*

14. Rather than stay in "pure" mathematics, you decided to do graduate work in _____What factors prompted you to go into _____?

(15. Probe for influential persons or factors which attracted or influenced respondents.)

16. Hit on 1–12 again. Probe for differences in comparison with undergraduate field.

* Asked only at the end of the second interview only if the topic had not already come up.

APPENDIX B

Profiles of the Respondents

Jennifer:

Jennifer was 40 years old at the time of the study. She had both a bachelor's and a master's degree in mathematics and was currently pursuing a PhD in mathematics education. She was married and had two sons, ages 11 and 14.

Jennifer liked math in high school and was influenced to go into math as a result of the positive influences of a male high school teacher who enjoyed math and made math fun for his students. She entered math in college without a clear idea of what one could do with a degree in math. She wasn't particularly interested in, or committed to, a career in teaching. Eventually, Jennifer took a teaching certificate because her father wanted her to have something to fall back on.

During her college years, Jennifer became preoccupied with her boyfriend and marriage plans. She went home a lot to be with her boyfriend and was not really interested in school or the math department except for her obligations as a student. Much of her support came from her roommate who was also a math major and with whom she took as many classes as she could. She finished her degree in 3 years and was anxious to get married. Her interest in teaching stemmed from its apparent compatibility with family life; summers and holidays off, shorter work days, and so forth. Jennifer worked as a full-time teacher and as a substitute teacher. She experienced breaks in her work career during the time of the births of her children and their preschool ages. Her family moved to this town for her spouse's employment, and Jennifer went back to school to earn a master's degree in mathematics. She was not aware of education as a separate field from mathematics. When she went back for her master's degree, she was not necessarily committed to teaching and was unsure what she would do. She was admitted conditionally by the mathematics department because she was older and had been out of school for awhile. All of her teachers were instructed to report to her advisor about how she was doing. She was the only student for whom this was the case. At the time it did not bother her, but now it does. She thought the differential treatment was based on her age and gender. She did not feel connected to the math department. She took her classes, but usually had to leave immediately to fulfill family duties. Additionally, she had started her degree as a part-time student.

After having proven herself, Jennifer began to feel more comfortable in the math department. She became friends with a few faculty who were close to her in age. The other students were nice to her. She observed PhD students in her classes and realized that she too could be successful as a PhD student. She began to realize that she would like to teach college mathematics and to do that she would need to get a PhD.

Jennifer observed that math department faculty set themselves apart from students, particularly undergraduates. Relationships were formal, and the joke among the graduate students was that getting a PhD in math meant "spending one's life in a closet with a light and a desk." She began to feel that her strength was more in working with people and did not observe that kind of orientation among math faculty. She decided a PhD in math was not really a career working with people; the commitment was to the discipline. She also believed that math graduate students put themselves on a pedestal and would often make derogatory remarks about other departments and their students. Her opinion was that many mathematicians lacked

social skills and tact and exhibited beliefs that work was the heart of what they did and that anybody could teach. She found mathematics education much more people-focused. People skills were important, and working on professional problems rather than just math problems was important to her. In her observation, the attitude of the mathematics education department was that teaching is important and not just anyone could do it well. The lifestyle in math education was what she considered normal, and she capitalized on what she viewed as her strength: working with people. Finally, she concluded that it was still hard for a woman to obtain a professional identity because society is not very family oriented. It does not give women the support they need. She believed many undergraduates still are not aware of the opportunities open to them with a degree in math. They still hold the stereotype of a grizzled grey-haired male professor; she perceived a need for more women faculty role models.

Mary:

Mary was 27 at the time of her interview, married, and expecting her first child. Mary had undergraduate degrees in both elementary education and mathematics. During the time of the interview, she had a MAT in math and was working on her PhD in mathematics education.

Mary's family encouraged the development of skills in areas of math and science during her preschool and elementary school years. By middle school, Mary was tutoring other students and had a math teacher who told her she was bright and should think of becoming a doctor. Mary's experiences with her mathematics courses in high school were mixed. She had an excellent and dynamic teacher for Algebra 1 and unremarkable experiences for geometry and algebra. At the end of her junior year, her counselor told her that she did not need to take precalculus even though she had grades of *A* in her previous courses. He instructed her to take psychology and humanities instead. Her father insisted that she take math her senior year. She was enrolled in a precalculus class with 3 young women and 27 young men and had a teacher whom she described as "sexist" as well as "incompetent" at both teaching and math.

By the time she enrolled in college, she hated math and lacked confidence. Therefore, she registered for the lowest level of math—finite— to satisfy the graduation requirements at a women's Catholic liberal arts college. On getting her schedule, she realized she was scheduled for calculus. Mary spoke with the math department head who said that, based on her SAT scores, she was qualified, and he would not sign the drop slip for her for at least 2 weeks. Mary had a fantastic experience in her calculus class, including an epiphany of sorts: Mary looked around the room on the first day and saw a classroom full of women and thought to herself, "All these women can do calculus." The professor was very influential for Mary. She eventually talked her into pursuing a mathematics degree, but Mary still did not let go of her declared major in elementary education.

Throughout college, Mary viewed her mathematics as an avocation. It was something she did to relax, and she enjoyed it, but she still envisioned herself as an elementary school teacher. She had very strong role models as mathematics professors. In fact, one (female) professor she spoke of was a runner, was married, and had children. She viewed that as a very positive influence on her thinking about women in mathematics. She graduated from college and became a high school mathematics teacher at a private girls' boarding school. Mary taught there for 3 years; each year she was given increasingly more difficult levels of math to teach, and finally, in her third year, she taught advanced placement calculus. This was very important for her

self-esteem and her sense of confidence. However, when she told the headmaster that she was leaving to enter a PhD program in math, he laughed at her.

Mary arrived at the university intending to earn a PhD in mathematics. When she arrived, she felt she was in "way over her head." She became part of a "math clique" in a graduate student residence hall. She and five men studied math together. Math was all-consuming, particularly for her fellow students. She began to realize she would not have a life if she stuck with math. She came to learn that the department did not value teaching, which she still viewed as her life. She heard about the math education PhD and decided to investigate. She viewed mathematics as too narrow a focus for her and had many negative feelings about the department. Toward the end of her brief tenure in the math department, a professor tried to encourage her to stick it out. He told her that her experiences and her knowledge were not bad compared to other students'. But by then, she had already had too many negative feelings and had already "disengaged from the department;" it was too late.

Claudia:

Claudia was 44 years old at the time of this study. She was married with two children, ages 15 and 11. She had earned a BA in mathematics, an MA in teaching, and was pursuing the PhD in math education.

Claudia enjoyed math in school. Her mother was a math major, so she became her role model, although her mother never used math professionally, except for a bit of teaching. Her father was a chemical engineer. She was attracted to the fact that math built on itself and was cumulative, and she liked abstract thought. She did not declare an undergraduate major immediately; she was equally interested in philosophy and religion. Finally, she declared a math major in her junior year in a default manner. She had a philosophy class on ethics that conflicted with the next math class that she would have to take (at a small liberal arts college). She chose the math class and felt from then on that it had dictated her decision to be a mathematics major. Claudia had a good undergraduate calculus teacher who was very influential. Claudia did not focus at all on teaching as an undergraduate major. She was not sure what she would do with the degree and really did not think much about that.

When she graduated, she felt she did not really have any real job skills. She had not emphasized computer courses like many of her colleagues and had not gotten a teacher's certification. She went on to graduate school to get more skills and because she wanted to learn more math. She always liked the prestige of being in math—there were few women in math. She felt that one had to be sharp and that it required more intelligence than other majors, but she had little sense of what one might do with that major, other than teach. She was relatively lonely as an undergraduate and did not fit in well with the other math majors. She had an unusual experience when she applied to a university math department to earn a master's degree. She was called by the wife of the chairman and told that, if she wanted financial support, she could have a fellowship in mathematics education. However, she would have to take an assistantship and teach, if she wanted a degree in math. On that basis, she chose the MA in education so she could get the fellowship. As she continued in math, she did not find it to be as much fun as she initially had. The general courses, to her, had pulled more aspects of the world together; she enjoyed viewing math as a unified whole. But, as she moved on toward graduate courses, she found the increasingly narrow focus, disenchanting.

Initially, she was interested in teaching and learning and in learning about people. She liked a more holistic approach to the world and really could not find that in the graduate courses that she took. Claudia liked abstract thinking and thought

women tended to be tuned into the nitty-gritty, everyday type of activities and situations. She believed that women tended to value, and be oriented to, particulars. She did not really understand gender differences in science and math but suspected they had something to do with nurturing. Over time, she had serious questions about mathematics teaching. She did not particularly enjoy her experience teaching high school math. She enjoyed math education because the content was broader than pure math. She was more interested in learning and in whether there are better ways to teach math than she was in finding a job. She liked the math education courses and definitely felt like she was part of a community.

Ellen:

Ellen was 47 and a Franciscan Sister at the time of this study. She had earned a bachelor's degree in mathematics and started a master's degree in mathematics but then switched to a major in early childhood education. During the time of the study, she was pursuing a PhD in curriculum and instruction with a major in early childhood education and a minor in women's studies. Ellen was heavily influenced by two female high school math teachers. They helped her develop an appreciation for the beauty and artistry of math. She also had two very good math and science teachers who demystified mathematics for her. Before high school, she did not like math very much. But she always knew that she wanted to be a teacher and felt committed to teaching fairly early in her life. She attended a small Catholic liberal arts college run by the Franciscans. She enjoyed studying math in the small, collegial department; the students worked mostly in groups, and knew the faculty well. All of her high school and college mathematics teachers were women, so she did not feel that mathematics was isolating for her as an undergraduate. She liked the theory behind math, but she was not at all attracted to its practical aspects.

Ellen was involved with a Franciscan order that emphasized education, so, by choosing that order, she had chosen to go into education. She had wanted to teach high school math, but was assigned to teach first grade. She was upset by this, but decided to accept the assignment. After working for a couple of years, she found that she enjoyed the community aspect of working in an elementary school. She found it rewarding to take children who knew nothing of reading and math and, by the end of the year, have them performing well in mathematics and reading.

Ellen started taking mathematics graduate courses at a midwestern technological institute while still teaching elementary school. They were a completely different experience for her than the math courses in her undergraduate days. She began to feel turned off by math as she experienced it in graduate school. She felt that mathematicians spent much of their time alone in an office working on theory and that mathematics was not about people. Additionally, she felt that a mathematician created something in his own space and women did not have a place in that world. She felt as if she had to prove herself, and she did, but she did not feel good about proving herself in that environment. At the graduate level, the focus was on math as a science that was very specialized and very competitive; the view was that real mathematicians did not teach grade school. She became disillusioned with straight math. She believed that subject matter was important, but her focus was on teaching the child, not teaching the subject.

She believes it is important to build programs around people, not fit people into programs. Now she would like to be involved with teaching teachers. She liked her current graduate department in the school of education, felt there was a collaborative effort, and was very interested in children and their lives and social justice.

Kate:

Kate was 41 and single at the time of the interview. She had no children. She had earned an undergraduate degree, a BS in mathematics, a master's degree in math, as well as in teaching, and was currently working on a PhD in mathematics education. Kate had graduated from high school, but she had not started college for 8 years. During that time, she married and began to work. Late in her marriage, she started college part-time, working on her bachelor's degree in mathematics. She did well as an undergraduate and felt that her husband viewed this negatively. He had gone to college, had done reasonably well, but had not completed a degree. When she was successful in her mathematics major, it became a point of contention with him, and they divorced 2 years after she began her work on her bachelor's degree.

Kate talked fondly of her experiences as a graduate student at a small regional campus of a major research university. There were only 17 faculty members; one woman was a tenured professor, and another woman taught in the department, though was not tenured. Kate talked extensively about the mentoring in math she received from the female faculty members. After graduating, Kate moved to a college town and began working on her degree in straight mathematics. She worked on that degree, as well as—toward the end—certification, so that she earned a mathematics master of arts in teaching rather than a mathematics master's degree. On earning her degree, she began teaching in a high school and then later taught at the university level at a regional campus. In 1991, Kate began more work on her mathematics education doctoral degree. Kate talked extensively about the contrast between her graduate study in the mathematics department and her graduate study in the mathematics education department. Kate felt that the work in the mathematics department was isolating and eroded her confidence. She felt like she had very little support, because of the larger department size, the lack of women, and the culture of the mathematics department. In contrast, Kate viewed the mathematics education department as more holistic, more concerned with the person, more concerned with people generally, and much more human. She felt much more support from and much closer to the math education faculty. She felt that they were also more accessible.

Kate said she thought that math was everywhere, described life, and was related to everything. She also thought math and math education were similar in that, though they dealt with different kinds of problems, both were problem-solving activities. She liked the problems in mathematics education better because they were related to people and were not so detached. Also, she added, "You have more of an excuse when you don't get the problem solved."

Pat:

Pat was 37, at the time of the interview, married, and had three children, ages 7, 9, and 10. She earned a BA degree in mathematics in 1976. She worked on a master's level psychometric degree at a small liberal arts college and was enrolled in the counseling psychology department at a large research university.

Pat attributes her decision to major in mathematics to her mother. She said her mother convinced her as a young child that she was smart, really intelligent. She felt like it was a goal of her mother's to convince her of that. As a consequence, when she went to college, she majored in mathematics to prove that she could do this thing that most people thought only men could do. She enjoyed mathematics as a game or puzzle. She double-majored in math and psychology, which she felt to be very interesting and more relevant to the world in general. She says she did not get any mentoring in the mathematics department-only men were mentored in mathematics

at the small liberal arts college that she attended. The ratio in that mathematics department was four men to one woman. However, she was mentored strongly in the psychology department and, from about the middle of her undergraduate years, they encouraged her to eventually seek a doctorate in psychology. An interesting point is that the psychology faculty encouraged her to keep her major in mathematics, rather than switch it to a psychology major. She was told that, later in graduate school, she could pick up graduate courses, but she could never undo the dropping of the mathematics major.

After college, Pat taught high school. Her husband was attending medical school, so her job was to help support him. Four years later, she had her first child and held various kinds of jobs. An important transition point in her life was when her husband, who was then a physician, became involved in racing bikes, had an accident, was injured, and became addicted to pain killers. That incident involved the entire family in ALANON. She was later asked to be a facilitator for beginning groups in ALANON (a support group for addicts and their families), and, because of that, her interest in counseling and psychology was rekindled. In 1990, she enrolled in the counseling and educational psychology PhD program.

When the advisor for the program learned that she was the wife of a physician, he laughed and said, "Oh, no!" He then (she thought) put her through a series of hoops before she was admitted. When he finally saw her GRE scores, which were quite high, he was convinced that she would be a good educational psychology major.

In her graduate program, Pat felt like she was mentored by a particular female faculty member. This mentoring was very important to her. Pat added that she had always valued math and psychology and that she had felt obligated to prove that she could do the math, because math was kind of a male thing. After she had proven her math ability, then she was free to pursue her true interest, which was psychology.

Terry:

Terry was 30 at the time of the study, married, with two children— a son, 4, and a daughter, 16 1/2 months. Terry earned an associate degree in mathematics from a small 2-year college and a BA in mathematics with an added-on teacher's certification from a small liberal arts college. She worked on a MS in mathematics, which she later converted to a mathematics education degree at an urban midwestern university. She was working on her PhD in mathematics education at the time of the interview.

Terry's earliest experiences in math in college were characterized by a small mathematics department. There were, perhaps, 15 students in the classes and only three or four math professors. She had the same professors for different classes and felt like she got to know them well. Terry taught high school math for a few years, and then she and her husband began looking for a place where she could earn a graduate degree in mathematics. She enrolled for her graduate degree in mathematics intending to become a teacher/researcher at the university level. As a part-time student, she found the experience at a large, urban university to be totally different from her undergraduate college experiences. She did not get to know the professors or other students well, except for one other woman in her classes. The material began to seem more difficult and also more pointless.

The mathematics department's expectations seemed to be for students to just work as hard as they could and spend as much time as possible on problems. In fact, she was taking one course and spending practically all her free time on it. She could not envision being a full-time graduate student in mathematics. The only

other woman in her classes, who was also a graduate student, was taking only two courses and had told her she could not imagine taking three mathematics courses in one semester.

While Terry was working on her master's degree in mathematics, she was also teaching high school math. Toward the end of her master's degree, she realized that she only had to take a couple of education courses to get a MA in teaching and be certified for life, so she switched.

In August 1988, Terry began a PhD program in mathematics education at a research university. Terry talked extensively about the differences between the mathematics department and the math education department and how the mathematics education department, with its focus on people, was more like what she wanted. Also, Terry had originally wanted to be a mathematics teacher the entire time she was majoring in math, unlike many of the students interviewed.

Notes

[1] See Rossiter (1978) for a brief discussion and analysis of similar concerns about the early part of this century.

[2] More than 28 hours of taped interviews resulted.

[3] One respondent objected to the original title of the article, "Dropouts From the Mathematics/Science Pipeline," because she and other interviewees subsequently entered mathematics education. Traditionally, mathematics education is not considered a part of the pipeline because it does not ordinarily lead to women in college classrooms and laboratories providing role models to aspiring scientists. However, S. Maple and I removed the word *dropout* from the title. The respondent also added to her description in Appendix B.

[4] Gilligan (1982) describes the typical female personality as one that defines itself in relation to other people. Kramer and Melchior (1990) found that young women thought more about role choices and the synthesis of family and work roles than did young men. They speculated that socialization differences between females and males might account for such differences. Ochse (1991) conjectured that genius has been so rarely evidenced in women because of a general lack of uninterrupted solitude, explainable, until recently, by dictated family roles.

[5] At the university in question, mathematics doctoral candidates serving as research associates earn approximately 30% more than education students in similar positions.

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