

Four Women's Motivation for  
Obtaining Graduate Degrees in Mathematics

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## Abstract

In 2004, only 30% of all full-time United States graduate students in mathematics were women. This study examines the reasons why four women pursued master degrees in mathematics, in the hopes of shedding light on the question: Why is it that women do not pursue graduate degrees in mathematics to the same degree that men do? Case analysis (both within and across) results are given. Among the results is that these women were attracted to mathematics majors as early as elementary school mostly because they were good in mathematics. These women were further encouraged along the way by family and/or mathematics faculty. Another very interesting study revelation was that none of the women was likely to pursue doctorates. The reason seemed to be the Mathematics Department atmosphere that informed these women that they would have to choose between a life of only mathematics and other interests (including having a family).

## Four Women's Motivation for Obtaining Graduate Degrees in Mathematics

Reasons why American women obtain graduate degrees in mathematics are not completely clear. Over the past twenty years, researchers have been concerned over the fact that considerably more men than women were pursuing mathematics majors and have studied if gender was a statistically significant factor in pursuing mathematics degrees (Haines and Wallace, 2002; Lackland and De Lisi, 2001; Trusty, Robinson, Plata, and Ng, 2000; Turner and Bowen, 1999). Although many more American women are pursuing doctorates in mathematics than they were twenty years ago, the numbers of women are still not equal to the number of men (Jackson, 2004). In the year 2003, approximately 41% of the undergraduate mathematics degrees in the United States went to females, and 30% of the full-time United States graduate students were women (Kirkman, Maxwell, and Rose, 2004).

Gender has been found to be a significant factor, but the reasons given as to why this occurs are varied. The number of high school mathematics courses taken (Ethington and Wolfle, 1988; Haines and Wallace, 2002; Maple and Stage, 1991; Trusty, 2002) and scores on standardized tests have predicted students' choice of career (Trusty, 2002; Turner and Bowen, 1999). In the recent past, females have earned fewer credits in more advanced mathematics high school courses (Davenport, Davison, Kuang, Ding, Kim, and Kwak, 1998; Haines and Wallace, 2002). But, even students' *perceptions* of their mathematics ability and whether one feels one will be successful in a mathematics major are key factor (Eccles, 1994; Trusty and Ng, 2000).

Women are under sociological (including gender role socialization) and cultural pressure (including peer pressure) not to pursue degrees in mathematics (Leslie, McClure, and Oaxaca, 1998). Parental pressure on women plays a large role as well (Dick and Rallis, 1991; Maple and Stage, 1991). Some women even describe themselves as having "difficulties in 'giving themselves permission' to choose" mathematics majors (Seymour, 1995, p. 450). Peer pressure includes pressure to please men, who have "an apparent difficulty in seeing physical attractiveness and intellectual capacity as other than mutually exclusive qualities in women who choose" mathematics majors (Seymour, 1995, p. 453). Negative experiences with mathematics faculty, including lack of female role models, and dislike for the atmosphere in mathematics classes are also problems for women (Seymour, 1995).

Psychological factors, including one's value system and the potential cost of pursuing a certain major seem to almost prevent women from pursuing mathematics degrees (Eccles, 1994). Potential cost may include money, time, energy, and cost to one's life style. For example, more women than men choose non-mathematics majors and degrees because they choose to spend more time with their families. Fewer women than men place humanitarian value on majoring in mathematics (Eccles, 1994; Lips, 1992; Turner and Bowen, 1999); i.e., fewer women than men think that being a mathematician contributes to what really matters in the world. More women than men believe that what is really important in life is helping each other, and careers commonly labeled in the helping professions (e.g., nursing) are a better fit for this value system (Lackland and De Lisi, 2001; Lips, 1992). Somewhat along this line is that fewer women than men claim to have interest in mathematics (Dick and Rallis, 1991;

Seymour, 1995). It may also be the case that more men than women “see the demandingness [of a mathematics major] as a positive feature, a source of status or of interest and motivation” (Lips, 1992, p. 79). For this previous reason, Lips (1992) suggests that researchers should not only focus on why women are not attracted to mathematics, but why men are.

Seymour (1995) has approached the question by investigating why women drop out of mathematics majors and has given these reasons: lack or loss of interest in mathematics, belief that another major would hold their interest, poor teaching in mathematics, and feeling overwhelmed by the pace or workload.

An interesting note, however, is that when mathematics ability is extremely high, no other influence (including interest level) seems to matter much (Dick and Rallis, 1991). But, do these reasons truly tell us what motivates female United States citizens to enter and complete mathematics graduate school?

In a comparative, heuristic, inductive, qualitative case studies approach, this study analyzes the transcripts from the guided interviews of four mathematics graduate students (who were audiotaped while being interviewed), in order to offer abstractions across the four individual cases. (See the appendix for the interview questions.) The author met with each woman separately, and simply asked the questions and allowed the interviewee to answer. In addition, the author, while under a single-semester level from her regular university, logged over 400 hours of observation of the Mathematics Department, including such activities as classes, meetings, and colloquiums. Using the issues approach (Stake, 1994), the topical issue is: *female graduate students in mathematics*. The foreshadowed problem is: *Most women do not find the study of*

*mathematics to be attractive, even among the subset of women who is highly capable of majoring in mathematics.* The issue under development is: *What motivates these particular four white females to study graduate mathematics?*

### Subjects

The four subjects were all masters-level graduate students at a United States Midwest research university; we will call it University U. The graduate program, offering a masters in mathematics, has approximately 20 graduate students per year, with roughly 50% U.S. citizens, 40% females, and 10% female and US citizens. The four subjects were Caucasian, female, and United States citizens. All were in their early twenties. All four were extremely valued by the Mathematics Department at University U, partially for their strong academic ability, but also for their superior teaching abilities. All four were removed from the normal recitation teaching assistant assignments, and given their own lower-level classes to teach. The four graduate students were not all in the same cohort. Miss S was finished with her degree before Miss K entered the graduate program. Miss K graduate the year that Mrs. H and Miss C finished their first year of the program. Thus Miss S does not know any of the other three, and Miss K knows of the other two, but they are not friends.

Miss K was interviewed one month before she received the MS degree. Her academic path had begun immediately after high school and occurred all at the same university, University U. She first earned an undergraduate degree in mathematics and computer science, and then, in the two years immediately following, she earned a MS in computer science. Directly from that graduate program, she entered the mathematics

graduate program, and took two years to earn the MS in mathematics. She next intended to pursue employment at a community college.

Miss S was interviewed approximately two years after she earned her MS in mathematics. She entered undergraduate college directly from high school. The college she choose was a highly prestigious college, especially in mathematics. She earned a bachelors in mathematics and mathematics education. She taught for a semester at a high school, and then entered the masters program at University U. After finishing the program, she accepted a teaching position at a community college (approximately 200 miles from University U). Miss S was in town for a conference when she was interviewed.

Mrs. H was interviewed at the end of her first year of graduate study. Mrs. H had earned a bachelors in mathematics and mathematics education at University U. She entered college directly from high school, but first entered a smaller, private college, and then transferred to University U. After earning a bachelors at University U, she entered the masters program. She also got married her senior year of the bachelor's degree.

Miss C was interviewed at the beginning of her second year of graduate study. Miss C left high school after her junior year and entered a prestigious, small, liberal arts college, at which she earned a bachelors in mathematics. She then went directly into the masters program at University U.

## Within-Case Analysis

### *Miss K*

Perhaps the most interesting situation within the case of Miss K is that she does not have a lot of intrinsic interest in mathematics. She had earned a masters degree in computer science, and during that period of time took mathematics courses from a professor we will call Professor B. Professor B, a male professor, offered considerable encouragement and attention to Miss K. When asked why Miss K pursued a graduate degree in mathematics, she credits Professor B with getting her interested in mathematics.

Miss K: I guess ah I kind of got talking with Professor B, he got me interested. I had a class from him. I kinda got to know him. I was his grader for that class afterwards. And after talking with him awhile, I kind of. Well, he kinda tried to pull me in. You know, twist my arm and everything. And well I think he did inspire an interest somewhat. Just made me realize that I would be good at that, or it would be a good thing.

Later in the interview, Miss K responded to a question about what mathematics departments could do to recruit or keep majors, and she returned to the concept of professors paying attention to their students.

Miss K: Professor B was influential in getting me here. That is definitely a good thing. Getting to know the professors. That personal attention. And professors getting to know you and seeing that you have a strength or an ability in trying to build something off of that. I think that played quite a role in me deciding to become a math major.

Despite Miss K's graduate pursuit being a rather last minute decision, she did feel good about her ability to do mathematics as early as elementary school. Miss K never felt that it was inappropriate for a female person to do mathematics, but, then, Miss K's father made his living as a high school mathematics teacher. Miss K does reference this fact when she said, "Well, I guess I have always been good at math and everything. Ah. Probably a gene thing."

Miss K had a great need for mathematics to be applied. She dislikes theory of any kind, including proofs. She wants to do applied problems, only. Miss K found it very difficult to define mathematics when asked. Interestingly, Miss K immediately answered "proofs" when asked what she liked least about mathematics, but paused for a long time and had to be asked twice to come up with what she liked best about mathematics. At the second prompting, she said:

Miss K: It is kind of fun to solve certain problems, especially if they are in areas that I like. Problem solving. Think about something. Come up with a solution.

Wanting to pursue this, I asked Miss K to think back to high school and what she liked about math then. Miss K again paused for a considerable period and then said, "Well, maybe because I was good at it. I came out strong."

Besides knowing that she was good at it, Miss K was very excited about the fact that other people thought she was good in mathematics. Miss K believed that she "stuck out as different," and she loved to be called a *math nerd* or *geek*. Actually, Miss K was quite different from most women her age in her appearance, mannerisms, and social

skills. Sometime following this interview, Miss K found it difficult to obtain work, which seemed to mostly be due to her odd behavior at job interviews.

Miss K was doubtful that she would pursue further degrees or employment in mathematics. She stated that she would definitely not pursue a doctorate in mathematics, for example.

Miss K: Um. Well, I think a Ph.D. in math a lot of times is more theoretical than I want. Finding new theorems and proving new theorems isn't all that exciting to me. But, applying the theory and coming up with a different algorithm, like you would in computer science, that interests me more. I think it is more practical. It can be applied to different applications.

However, Miss K did think she might teach mathematics someday. Miss K talked about how much she loves to teach, and when I asked her why she loves teaching so much, she said this:

Miss K: I guess I like working with students and helping them learn. It makes me feel kind of useful and significant. You know, applying my knowledge and my talents and abilities to help others, to inspire interest, and ah, you know helping them to get a degree and a career choice and everything. Being a part of that. That you can make a difference to somebody.

In Miss K, we find a very capable masters student (recall that she had already completed a masters of computer science). And yet, with Miss K it seems that there is not a strong affection toward mathematics in the traditional sense, but an attraction

toward being good at mathematics. When her strengths are recognized by others (including, but not limited to professors), it seems to cause Miss K to want to do more with the major. Further, she seems attracted to teaching mathematics to further show people how good she is in mathematics and to possibly attract others to the field.

### *Miss S*

The largest influence on Miss S has been and is her family. Miss S's father is a mathematics teacher, and her uncle is a physics professor. From the time Miss S was very young, she was told that studying mathematics was very important. Miss S believes that studying mathematics makes the mind stronger, much like jogging will make the body stronger. In fact, this analogy holds well for Miss S, who is also a good athlete. Miss S is constantly busy working on her mind and/or body. She views this as one's duty in life, and she views herself as a happy member of a family with this philosophy of doing one's duty.

Miss S has almost no desire to obtain a Ph.D. in mathematics. Miss S took a position as a community college instructor, and seems to have settled into a life that would not allow for the rigors of a doctoral program. Miss S does continue to take graduate mathematics and mathematics education courses at various universities in her area, but these courses will not lead toward a doctorate. She takes one course each semester, including summer. She also earns extra money writing solution manuals for mathematics textbooks. It seems to be the case that Miss S believes that pursuing a doctorate in mathematics would take all her time and energy. Although she is committed to building her mind, she is also committed to other areas in her life. Thus,

she chooses to continue in mathematics in these manners named and not by pursuing a doctorate.

Miss S made statements frequently during the interview that expressed that she "always knew" she would get a math degree. Yet, at the same time, she talked about many different majors that she considered, and spoke of liking them as much as she likes mathematics. Some of these majors are art, physical education, and public speaking. When confronted with the apparent contradiction (i.e., always knowing it was mathematics and thinking of all these other majors), Miss S responded, "Yes, but I always knew, though, that math was the one. But, it was kind of like, if I had the time, I'd do this and this. You know?"

Miss S seemed to find it sad that most people think majoring in mathematics is "bizarre." Miss S said that if people were given a chance to see what mathematics really is, people would want to take more mathematics courses. Further, she said it is just not true that one has to be "really smart" to do well in mathematics. Miss S's own approach to mathematics learning seemed to be to "plug away at it" and just keep trying. After trying, she felt good because she "made it through." She "survived it."

*Mrs. H*

Mrs. H has enjoyed doing mathematics since the time she was in elementary school because it was something she was "good at and stood out at." Mrs. H believes that people are "called" to do what it is that they "stand out at doing." It was not until late in her junior year of her bachelor's degree in mathematics that Mrs. H began to feel a "passion" for doing mathematics. It seemed to be the case that had Mrs. H never felt that passion, she would not have pursued the graduate degree in mathematics. Yet, she

did pursue and do very well in the bachelor's degree in mathematics with no sense of "passion" for it. (Mrs. H won University U's Outstanding Undergraduate in Mathematics Award the year of her undergraduate graduation.) Mrs. H talked quite a bit about how doing mathematics took a shift for her from "wanting to do mathematics because it was easy and [she] was good at it" (thus she felt she should) to "wanting to do mathematics because it was hard and it was a challenge" (thus she felt good when she did it).

Mrs. H also really enjoyed the special status she felt for doing (and being able to do) graduate mathematics. She likes the special attention she gets, and the idea that everyone thinks she is really smart. In addition, she feels that being a female in graduate mathematics is a "status thing, like, oh, she is really smart. She is a girl and she still does math." Mrs. H likes to identify with other mathematicians, and talks about how much she likes watching movies like *A Beautiful Mind*. Consider this statement by Mrs. H.

Mrs. H: But, I want to be a little different. And I find that when I discuss it with other people. Even when I tell people that I am a math major, and they say, "I'm not good at algebra", or whatever, it is recognizing that portrayal. "I'm not one of you."

Mrs. H also remarked that even if she won a million dollars, she would want to finish a graduate degree in mathematics. "It feels really important to me," she said. However, when asked if Mrs. H will pursue a Ph.D. in mathematics, she talks about the need to balance work and family. She said, "It goes back to being a woman and I do actually have a desire to possibly not work full time. I don't want to go through my

whole life being so busy that I miss it." Since Mrs. H is married, she has decided that in her household, her husband's job comes first. (Her husband has a bachelor's degree and is an accountant.) Interestingly, although there is evidence that Mrs. H is one of the strongest graduate students (her test scores and grades would support this), during the second year of Mrs. H's study (following her interview for this study), Mrs. H had become viewed by some faculty in the Mathematics Department as a weak student and possibly not capable of pursuing a Ph.D. in mathematics. This seemed to be based on two things: One, Mrs. H has an interest in mathematics education (and that is viewed as a route for weaker students) and, two, Mrs. H expresses her desire to spend time with her family. The Mathematics Department at University U is made up of 25% married couples (i.e., both the husband and wife are mathematics professors in the department; they were hired as a pair), 6% women, and 69% men. One of the women from a married couple is not a mother, but the remaining women in the department are mothers. The woman without children makes it known that it is not possible to be a successful mathematics professor and raise a family, and therefore is constantly criticizing the remaining women professors. Interestingly, the husbands of the married professors with children take almost no responsibility for the children and household; thus leaving the females with full-time positions plus responsibility of the children, while the husbands have only full-time positions (although the positions are identical in all ways, even salary). Also quite interesting is the significant degree to which the men in the department seem to believe it is true that women should not raise families and hold professor positions. The men repeatedly tell graduate students that the fact that their wives are "stay-at-home" moms is why they [the men] have such successful

careers. Although the men seem to view themselves as being gracious in their comments about their wives, they do not seem to understand the atmosphere that seems to result. As this entire situation is known by the female graduate students in the department and, at least for Mrs. H, seems to carry a strong message to female graduate students that they will need to pick between family and careers.

In sum, Mrs. H has considerable talent in mathematics, of which she is aware. At first, Mrs. H pursued mathematics because she knew she had talent. Later, Mrs. H pursued mathematics because she felt a "passion" for it. Mrs. H may, however, end up leaving mathematics because the department has presented to her the idea that she should choose between mathematics and family, and Mrs. H chooses family.

#### *Miss C*

Miss C is very clear that she has liked mathematics and been good at mathematics since the second grade. Miss C never had any doubt that she would major in mathematics, and once she started a bachelors in mathematics, she knew she would earn a masters, as well. Miss C sees mathematics as a very exact science, using words like *precise, correct, no gray, analytical, perfect, and right*. Miss C says that when it comes to mathematics "you can work very hard and you *know* you will get the output you seek." She sees mathematics as a non-creative activity, as well.

Miss C comes from a family of successful women, and so being a female in mathematics was never an issue for her. Miss C loves the subject of mathematics, and not only needs no outside motivation to study it, nothing or no one seems able to distract her from it. Applications mean nothing to her, and when asked what a department could do to attract more people to mathematics, she thought a department

might offer more mathematics courses! There is no part of Miss C that even seems to comprehend that someone might not enjoy studying mathematics.

Miss C's definition of mathematics is that of an algorithm to solve problems. She feels that no other subject is as important as mathematics, or even is anything worth doing, since everything else is memorization, according to Miss C. Miss C says without hesitation, "I look at math as the best." Miss C says she will have a long future in mathematics (although this may not include pursuit of a doctorate), and worries that current reform in K-12 mathematics education will ruin mathematics for future students.

### Cross-Case Analysis

#### *Five Similarities*

Analysis of the data revealed five emergent themes. The first was the fact that all four women were very talented at mathematics and quite aware of their talent. In addition, all four women were very successful in all areas of academics. Results on standardized tests, for example, were extremely high for all four women. All four women obtained bachelors in mathematics with A averages, and Miss C and Miss S attend very prestigious undergraduate institutions. (Miss K and Mrs. H did not go to prestigious institutions, but, of course, this is not to say that they could not have.) All four had outstanding grades as graduate students, as well. Miss K had already earned a graduate degree in computer science, during which she won the Outstanding Graduate Student of the Year Award. There is little question that each of the women could have pursued any academic career path that they desired. In fact, Miss C remarked that she considered medicine, but thought it would not have been enough of a challenge, since

medical degrees are "mostly memorizing." Some of the women also had non-academic talents, but these were not uniform. For example, Miss S is a very gifted athlete, while Miss K appeared to have no interests what-so-ever outside of academe. Although the women differed in level of self-confidence (to be discussed later in this paper), all four women were able to state the facts, as they were. For example, all four women were aware of their scores on testing, their undergraduate and graduate place standing (as compared to other students, for example), and the fact that they were viewed by graduate professors as talented and bright people.

The second commonality was that all four women were successful at and interested in mathematics very early in elementary school. All four women referred to doing and enjoying mathematics in elementary school. All four women found mathematics easy in elementary school. Moreover, mathematics was such an enjoyable process that all four sought "extra" opportunities to do mathematics. One remarked that during elementary school she was always "taking whatever advantages I could take," meaning that she tried to work on mathematics whenever she could. Two sets of quotes, one from Miss C and the other from Miss K, will illustrate this point.

Miss C: Well, I would probably say that I can remember like second grade, like thinking that math was something that I definitely liked. You know when you take those tests? Like those standardized tests? My math would be literally 100, you know percentage wise. ... So right away, I knew I liked it and I knew I was good at it.

Miss K: Well, I guess I have always been good at math and everything ... Math has been something that has always come to me. And I know that like

when I took the standardized tests, math would always be my strong part. I mean the scores clearly show that.

The third theme was in common to three of the four women (not in common to Miss K) and has to do with the women's view of applications and mathematics. Three of the women appreciated mathematics for mathematics sake, and did not care if the mathematics eventually led to solving applications. In fact, these women each remarked that the applications part of mathematics was their least favorite part. Miss C remarked that “too much application bothers me.” Mrs. H offers a nice summary.

Mrs. H: I feel like 95% of the time, there is no application. I only remember one class that was application oriented. I'm not studying math to use it that way. I'm studying math itself. Not how to use it. I mean, like with number theory, there are no applications. Well, I'm sure there are applications, but ... I do get concerned what is this good for? Why am I? I suppose that crosses my mind. But, math is not meaningless in any way. I am using my mind and thinking in a new way. I'm not pursuing it because of applications. Although, obviously, applications are good.

The fourth theme was revealed when the women were asked to define mathematics. All women described mathematics as a problem-solving discipline, although Miss K took considerable time in coming to her definition.

Miss K: [long pause] I want to say maybe a problem solving process. A logical thought. A theoretical thought.

Miss C: I guess the very broad definition would be like a logarithm [sic] to solve a problem. It doesn't have to be numbers I think. I mean

technically it is numbers but I wouldn't say that. It is just problem solving. And we developed numbers and symbols to do that. But, I think it is just problem solving.

Miss S: Oh! A Definition of mathematics. [long pause] Well, gosh, my definition of mathematics keeps changing because like with discrete mathematics, deals with a lot, but not with numbers. You know math is a lot of different things besides numbers. A lot of people think that math is balancing your checkbook. Of course, I don't think that. In fact, I write one check and then use my credit card! [laughter] People who say that they cannot balance their checkbooks, well, I don't balance my checkbook. It could be bouncing right now! [laughter] So, for me, I just think of it as a way of thinking, as a way of, it is just logic.

Along this same line of problem solving, Miss S remarked that her favorite thing about mathematics was “how it pushes you to think.” She expands on this thought in the quote below.

Miss S: My great uncle who is a physics professor at Kent State, he and his brother, who works out at NASA, told me “Oh, you can never have too much math.” And that is kind of my thought. Even though everyone is saying, “Oh you have to have everyday math.” But, it is a way of thinking. Like why do we read about World War II? Well, it makes us think about where we are in society today. Well, it is the same thing with math. Even though you don't think of it as finding the integral of

something being like going to the grocery store, it just pushes your brain to think in a neurological method.

The final theme was that all women viewed studying mathematics as fundamentally different from studying any other subject. Whether the women are correct in their ideas or not, all four women seemed to view studying non-mathematical subjects as a memorization process, and studying mathematics as an active, problem-solving process. Each of the following quotes is a response to the question: Do you find studying mathematics different from studying other subjects?

Miss S: Yes! I *loved* studying math because I felt that I was involved in the learning. Where in psychology and history, and you know, not to pick on these subjects, because they are all great subjects, you know if I go back I would love to re-take all my classes, because I know that I would gain more from them. But, there I just read, and read, and read, and then we would discuss in class. Where in math, I read, like the chapters were four pages, where you had to read a hundred for English. Then I did problems, and I actually felt that I was, it was interactive, and I like that about studying math.

Mrs. H: Yes. I study math primarily by I review through the book again, and try to remember procedures. But, for anthropology, it is more memorizing. You know, find the main ideas. Math is more, you have to do problems. Yes. So, it is different. You don't study for anthropology by writing down questions and trying to answer them.

You just read through the material. Math is a lot more problem oriented.

Miss K: Other subjects, especially liberal arts classes, you have to do a lot of reading, like of the textbook. And it is more memorization. Whereas in math, you have to understand the concepts, and not memorize. Not as much reading of the textbook like you would in other subjects. You have to go through it more carefully, and understand what is going on, rather than just kind of reading it. Picking up facts.

Along this same line was the shared thought that mathematics is different from other subjects in demanding less creativity and allowing more of a sense that one has (or has not) come to the one, correct answer. A quote from Miss C illustrates this thought.

Miss C: The main thing I like about math is it is precise. It is correct. Or it is not correct. I have a hard time with anything in life where it is gray. Or where there are decisions to be made. Like you could read a paper and one person will say, "Well, I think it had this tone." Or it was this. And another person will say this. In math or in most math cases, there is going to be an answer, and it is going to be the right answer, or you are going to be able to tell. I think even when I was young, I was very analytical, and very perfectionist. I needed to know. I needed to know when things were right. And when things were wrong. That is the main thing. You can work very hard and you *know* you will get the output you seek.

## Five Differences

The women also revealed differences that could be categorized into five themes. The first difference was that the women's self-image and level of self-confidence varied. Although the women were initially viewed as equally valuable in the department, the women did not view themselves in the same manner. (Mrs. H seemed to lose some of her standing with the department sometime after her interview.) Miss K viewed herself as clearly the best graduate student who had ever entered University U. She was constantly offended that the department was not treating her better. She thought that she was a very gifted teacher, and was constantly suggesting that others (including professors) should observe her teaching. In fact, Miss K stated that she had "given up everything else for mathematics." On the other extreme, Mrs. H felt that she was unworthy of the department. Miss C seemed to be somewhere between Miss K and Mrs. H. And Miss S actually described how her self-esteem had improved throughout the process of pursuing degrees in mathematics.

The second area in which the women differed was the degree to which other's opinions of them mattered to them. The third area was the level of family support that the women enjoyed. Since these themes are closely related, we will discuss both together. In particular, the women were asked about society's view of mathematics and how that affected them. Miss K seemed to be enthused with the idea that people think she is not only smart, but a nerd. In fact, Miss K seemed to take opportunities to promote that point of view, and made numerous remarks about it, while laughing.

Mrs. H, who is a religious person, seemed more concerned that people might think she thought herself superior to her father, who is a mechanic. She felt that

pursuing degrees in mathematics might appear uppity to people, and this bothered her. In fact, it bothered her enough as to place pressure on her not to pursue mathematics degrees. Mrs. H also had recently married, and she seemed very concerned that she not play a role in her marriage that made her husband feel inferior to her.

Mrs. H: I'm always thought of as a really smart person. My dad is a mechanic, and I totally admire that. I even admire it more than people who are academic, because I can't do that. I can't fix a car, and all that stuff. So, I have this persona, and this image of being extremely intelligent. I have that image in my family. But, it is book intelligent. Not necessarily that I know how to do everything intelligent.

Author: And [your husband] is kind of in the same field. So, he didn't feel, oh, I don't want to date a math person.

Mrs. H: No, he didn't feel that way. But, he does view me as really smart. He brings that up in conversations. I am just viewed that way in general. Just because it is math. And not because it is necessarily true. Even with my own family. I think [my sister] is one of my closest friends, and she saw me growing up, and I think she sees me as normal, but everyone else thinks I'm really smart.

Author: How do you see yourself?

Mrs. H: It is hard not to believe it when everyone else thinks that. I am very aware of the things that I can't do. I am appreciative of the things that I can't do. My dad is a mechanic and I'm really admiring that. Not that it is more important. Although it is more practical. Even though it isn't

revered, I really admire it. So, there are intelligences in all sorts of areas.

But, at another time, Mrs. H was expressing that she was inspired to work at mathematics because of the negative portrayal of mathematicians in popular culture. For example, at one point in time, Mrs. H described how she loves to watch *A Beautiful Mind*. In the quote below, she is describing the inspiration she gets from popular culture's portrayals.

Mrs. H: That inspires interest in it for me. And it totally affects math. I think a lot of people go into math because of the cultural portrayals. And they don't know that they are doing that. The cultural portrayal attracts people to mathematics because it is intriguing. I find it absolutely fascinating. And it is accurate. Sure, it isn't the best portrayal, but read about math history. And you will find that that is how mathematicians are.

Miss S described wanting to please her parents, and, in particular, her father who made his living as a secondary mathematics teacher. Miss S also remarked that she found it "crazy" how people were always saying to her "Oh, wow. You must be smart." as soon as they find out that she has a mathematics graduate degree.

Miss C described the fact that all the women in her family had at least master degrees. Her grandmother held a Ph.D. in science education, a fact that had considerable influence on Miss C.

The fourth difference was that the women differed in their intrinsic view of the worth of the degree. The women were asked if they would have majored in

mathematics had there not been any work in the area. Mrs. H seemed to fully believe that mathematics graduate degrees were not applicable to anything, while Miss K believed that the question was impossible to answer because “I am definitely going to get something out of it somewhere. I’m not sure that I could say yes to that because I feel that no matter what, I will get something out of it.” Miss S stated that she liked mathematics so much that she would have gotten the degree anyway, but she also would have double majored.

Mrs. H: I don't really think there is work in the field, and I felt that way when I was getting the degrees. So, maybe that isn't answering your question, but I guess, yes, I would still, because that is how it felt to me. I mean, I guess if I had thought that definitely 100% math would do me no good, then I may have looked into something else. But, I always kind of thought that there was no clear-cut thing that you could do with math. I would at least have tried to fit it in, though, even if I went with something else. I didn't really know what I was going to do with it when I was getting it. You know I would get those lists from the office [The department kept lists of occupations that mathematics majors held.] and I would write a letter to a company, saying, I don't know exactly what you want, but here is what I know. I mean you could be a mathematician or a math teacher. But, you really don't become an accountant. You know. I guess I didn't really enter it knowing what I would do with it. I just felt compelled to do it. Also, with math classes,

I never wanted to be left behind in case I needed it later on or something. So, I just kept taking it. I don't know if that answers.

Finally, the women differed in their level of commitment to mathematics in their future. Miss C simply said "yes" when asked if she would stay with mathematics, while Miss S remarked "for sure." Miss K felt it was fairly certain that she would switch to computer science, or something else. Mrs. H remarked as follows:

Mrs. H: I think I will always use it. I will always use what I learned. But, I could see myself. I don't plan on leaving it. But, I could see myself ending up somewhere differently. Partially because I don't know what you can do with some of it. But, also because I have other interests and other passions I can see myself eventually going into.

#### Discussion and Some Implications

All four of the women were attracted to the field of mathematics in elementary school. Although we certainly cannot conclude that all women make up their mind about being a mathematics major in elementary school, it is safe to conclude that for some the interest begins there. Implications clearly include a close examination of our elementary mathematics programs. For example, we might consider having mathematics specialists teach elementary mathematics, instead of leaving it to the generalist (i.e., the regular elementary teachers who may or may not have profound understanding of mathematics). Another implication may be to consider carefully what it means for elementary students to feel successful in mathematics. For the four women in this study, each felt very good about their standardized mathematics test scores. As elementary curricula changes, so do the standardized tests. What affect, if any, will this

have on future mathematics majors? Are there other methods that might result in more students feeling successful at mathematics early in their elementary years?

Although the women felt good about their master degrees and were sure that they would continue to have some connections to mathematics, it is a strong possibility that none of the four women will pursue doctorates in mathematics. Why is this? All four women are very capable of pursuing doctorates. It seems clear that for at least two of the women (Mrs. H and Miss S), the women believe that they must make a choice between doing only mathematics (and thus earning a doctorate) and having a life beyond mathematics (including but not limited to a family). Miss K also believed this and seemed bitter that although she was willing to "give it all up for math," the department did not seem to appreciate it. There is evidence that the Mathematics Department at University U sends a message that it is not possible to be successful in mathematics and have a happy family. Is it true that women must choose between mathematics and family? Does the mathematics profession need to accept that women will never be a large percentage of mathematicians? Or are there solutions to this? Can mathematics departments adjust to make it more likely that both male and female mathematicians will have time for their families? If it is nonsense that women cannot find time for mathematics and other interests, then why are these messages being sent?

Cultural portrayals of mathematicians seem to have both the affect of drawing these four women into mathematics, and keeping them from wanting to pursue further mathematics. Again, we might ask ourselves if there is any truth to cultural portrayals. If so, what should our reaction be, and if not, how can we combat it?

Ability seems to be the least concern in terms of drawing women into mathematics. All four of these women had ability, knew they had ability, and pursued mathematics at least partially because they thought they were good at mathematics. However, so many other considerations came along to both keep these women in mathematics and urge them not to continue with mathematics. Some of these considerations seem beyond society's control (e.g., a family with strong connections to mathematics, two of the four women had father's who were mathematics teachers). But, other variables seemed to be a matter of interpreting their role in society, and seeking outside support. Although men may also require support in order to pursue mathematics majors, it is fairly clear from this study that many outside variables came together to allow these women to pursue mathematics degrees and then to prevent them from continuing to doctorates.

### Conclusion

All four women are talented in mathematics and aware of their talent. All women were successful at and interested in mathematics starting in elementary school. The women viewed mathematics as a problem-solving discipline and three of the four valued mathematics even without applications. All four women viewed studying mathematics as different from studying other subjects (which they tended to view as memorizing).

The purpose of case studies is not to come to generalizable conclusions, and, indeed, we do not know to what degree these commonalities are in common to other women in mathematics. Further, due to who was not included, we do not know to what

degree men share these characteristics, nor even to what degree women who have chosen not to be mathematics majors also share these characteristics.

We do, however, gain a qualitative, in-depth examination of four women's motivations for pursuing graduate work in mathematics. These women pursued a degree in a subject they felt they had talent (and evidence showed they had talent) and had outside support. Further, and perhaps the more important conclusion, these women probably will not seek further degrees (such as a doctorate) in mathematics not due to lack of talent, but to lack of outside support. These women were in a department that clearly sent the message that women should not combine family and mathematics. At least three of the four got this message, with two (Miss S and Mrs. H) choosing not to continue in mathematics, and Miss K willing to not have a family. Is this an appropriate message to send to these women?

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## Appendix: The Interview Questions

1. Trace your academic life (put it in context with your life story).
2. How did you decide to become a math major?
3. Were there other majors you considered?
4. What do you like best about math?
5. What do you like least about math?
6. Were you ever discouraged, and, if so, what caused the discouragement?
7. Were you ever particularly happy as a math major, and, if so, what caused that happiness?
8. Did you ever not want to be a math major?
9. What is your experience as a female in math?
10. Would you have majored in something else if you knew there was no work in math?
11. Did you find the study of math different from the study of other subjects?
12. What were your study habits (how hard did you have to study mathematics)?
13. In order to be motivated, do you need to see an application for the mathematics that you are studying?
14. What was done right for you to encourage you to stay in mathematics?
15. What advice could you give an undergraduate or graduate mathematics department in terms of attracting and keeping majors?
16. What is math?
17. What is your reaction to cultural portrayals of mathematicians?
18. What do your friends feel about mathematics?

19. Tell me about your parents' and siblings' reactions to you being a math major.

(What do the parents and siblings do for a living?)

20. Do you see yourself staying in math all your life?