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ORIGINAL ARTICLE

Images of mathematicians: a new perspective on the shortage of women in mathematical careers

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Abstract Though women earn nearly half of the mathematics baccalaureate degrees in the United States, they make up a much smaller percentage of those pursuing advanced degrees in mathematics and those entering mathematics-related careers. Through semi-structured interviews, this study took a qualitative look at the beliefs held by five undergraduate women mathematics students about themselves and about mathematicians. The findings of this study suggest that these women held stereotypical beliefs about mathematicians, describing them to be exceptionally intelligent, obsessed with mathematics, and socially inept. Furthermore, each of these women held the firm belief that they do not exhibit at least one of these traits, the first one being unattainable and the latter two being undesirable. The results of this study suggest that although many women are earning undergraduate degrees in mathematics, their beliefs about mathematicians may be preventing them from identifying as one and choosing to pursue mathematical careers.

Keywords Gender · Identity · Images of mathematicians

1 Introduction

Current research has shown that gender differences in mathematics achievement are quite small and are continuing to decrease with time (Boaler, 2002; Fox & Soller, 2001). When gender differences are noted, frequently the differences are not statistically significant and do not consistently favor a particular gender (Hargreaves, Homer, & Swinnerton, 2008). For example, although some large international studies report that there are gender differences in mathematics achievement that favor boys, in some countries (such as Iceland and Thailand), girls consistently outscore boys (Wallon, 2005). Furthermore, in the United States, girls and boys enroll in equally difficult high school mathematics classes, however, girls earn higher grades in mathematics. In college, men and women earn similar grades in mathematics classes, when the classes are matched for difficulty level of the course (Spelke, 2005).

Despite the absence of gender differences in mathematics achievement, women remain underrepresented in the field of mathematics. This under-representation of women, however, is not significant in the United States until the graduate level and in the workforce. During the years from 2000 to 2004, women in the United States earned 48% of the bachelor's degrees in mathematics,[1] yet women only earned 43% of master's degrees and 25% of doctoral degrees in mathematics (NCES, 2001–2005). Furthermore, the proportion of women recent-PhDs currently being hired as faculty in mathematics departments is lower than the proportion of women receiving doctoral degrees in mathematics (Gordon & Keyfitz, 2004; Sharpe & Sonnert, 1999). This trend of low participation exists in other mathematics-based careers[2] as well (NSF, 2004).

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[1] Note that 57% of the total bachelor's degrees earned during this time span were earned by women, so this number appears more equitable than it is (NCES, 2001–2005).

[2] For the definition of mathematics-based careers, I am using the National Science Foundation's definition of mathematical scientist as defined by the National Survey of Recent College Graduates (NSF, 2006). An occupation as a "Mathematical Scientist" includes: actuaries, mathematicians, operations research analysts, statisticians, technologists/technicians in the mathematical sciences, and other mathematical scientists, including postsecondary professors of mathematics or statistics.

Therefore, though a significant number of women are choosing to earn undergraduate degrees in mathematics, they are not obtaining careers in this field at the same rate as their male peers.

Though women are earning fewer graduate degrees in mathematics and are less likely to enter mathematics-based careers than men, this trend cannot be generalized to graduate education or the workforce in general. The Chronicle of Higher Education (2006) noted that in the academic year 2001–2002, women earned 59% of all of the master's degrees and 46% of all of the doctoral degrees awarded in the United States. Furthermore, in the year 2004, women constituted 47% of the college-educated workforce (BLS, 2005). Therefore, women in the United States constitute a substantial portion of the college-educated workforce and those earning graduate degrees. They are simply not doing so in the field of mathematics. In light of this, one may ask: Why are women choosing to study mathematics at the undergraduate level at the same rate as men but then are not pursuing graduate degrees in mathematics or mathematics-related careers at the same rate as their male peers?

2 Review of relevant literature

A number of possible reasons as to why women do not enter careers in mathematics are discussed in the literature. One seemingly influential reason is gender differences in self-confidence in mathematics (Davenport, 1997; Fox & Soller, 2001; Seegers & Boekaerts, 1996). Men report higher levels of confidence in their mathematical abilities than women do. These results are not dependent on the gender of the students' mathematics instructor and remain true even when differences in performance have been accounted for (Hughes, 2000). This trend has even been found amongst high-achieving students who have been labeled as mathematically "gifted" (Hargreaves, Homer, & Swinnerton, 2008). While women tend to underestimate their mathematical abilities, men often overestimate their abilities, making the apparent discrepancy in achievement appear even larger.

It has also been noted that women receive less encouragement to study mathematics from parents, teachers, counselors, and peers. While overt references to gender-role stereotypes are not as common today as they once were, women often face subtle discouragement by "significant others" in their lives from entering mathematics-based fields (Bartholomew & Schnorr, 1994; Fox & Soller, 2001; Sadker & Sadker, 1994). Even women at the undergraduate and graduate level who have demonstrated both interest and talent in mathematics continue to endure messages from their professors that they are not being taken seriously as mathematics students or that they do not belong in the field of mathematics (Herzig, 2004; Hughes, 2000).

This lack of encouragement for women in mathematics is likely a result of the traditional stereotype that mathematics is a male domain. Both parents and teachers alike have demonstrated the belief that boys are more mathematically capable than girls (Raty, et al., 2002; Tiedemann, 2002). Furthermore, when girls are successful in mathematics, this success is more often attributed to "effort" and "hard work" rather than "talent" or "ability" (Jones & Smart, 1995; Raty, et al., 2002). Recently, work by Forgasz, Leder, and colleagues has suggested that this traditional belief of mathematics as a male domain may be changing (Forgasz, Leder, & Kaur, 1999; Forgasz, Leder, & Kloosterman, 2004; Forgasz & Mittelberg, 2008; Leder & Forgasz, 2002). Data has been collected on students' beliefs about mathematics as a gendered domain from students in grades ranging from 7th to 12th from schools in Australia, Israel, Singapore, and the United States. Though beliefs varied slightly from country to country and between genders, the overall trend remained the same. Although some students in each country claimed mathematics to be a male domain, the majority of the students in these studies reported mathematics as a gender-neutral domain, and still some reported the field to be a female domain. In one of their earlier studies, however, these scholars noted inconsistencies between some students' reported beliefs and their in-class behaviors (Forgasz, Leder, & Gardner, 1999). For example, one student who claimed that it was sexist to say that either sex was better at mathematics frequently used sexist language, taunted the girls in his study group, and refused to cooperate with them on mathematics assignments. It is unclear whether such inconsistencies would be isolated occurrences or more widespread. Therefore, while it appears that many secondary school students no longer attest to the belief that mathematics is a male domain, more work is needed to determine whether or not this belief plays out in their actions. Furthermore, this work, thus far, has been conducted with 7th to 12th grade students. It is important to extend this work to determine whether these students continue to hold their gender-neutral beliefs into adulthood where the difference in participation is currently most notable.

Exploring the societal perception of mathematics as a male domain is not only relevant to the participation of women in mathematics, but also to their achievement. It has been shown that the traditional belief that men are better at mathematics than women can, in turn, affect the mathematics achievement of women. This phenomenon is what many scholars refer to as *stereotype threat*. Stereotype threat is the "psychological threat associated with the awareness that one may be viewed through the lens of a negative stereotype" (Pronin, Steele, & Ross, 2004, p. 152). As such, a person who is aware that they possess a trait that is often associated with achieving poorly in a subject, such as their gender or ethnicity, may actually demonstrate lower levels of achievement in that subject as a result. Numerous studies have shown that women who are either reminded of the stereotype that men are more successful in mathematics than women, or told nothing with respect to gender, prior to taking a mathematics test score lower on the exam than equally qualified men. When women are told prior to taking the same exam that no gender differences are produced by the test, they tend to score as well as men (Quinn & Spencer, 2001; Spencer, Steele, & Quinn, 1999). It is believed that in this latter case, the stereotype threat has been reduced, allowing the women to complete the exam without the concern of being judged by the stereotype. Therefore, the traditional belief that men are better at mathematics than women plays the role of a self-fulfilling prophecy.

Women may also be discouraged from entering the field of mathematics through subtleties found in mathematics textbooks. Women tend to be represented less frequently than men in mathematics texts. Furthermore, when mentioned, women are more likely to be portrayed as playing a passive role and to be demonstrating gender-stereotypical behavior (Clarkson, 1993; Davis, 1997; Walkerdine, 1998). This was true amongst photos, drawings, and written text found within mathematics textbooks. Furthermore, recent studies of current science textbooks report similar results (Elgar, 2004).

The mathematics curriculum and teaching environment also influences the loss of women in mathematics through means other than textbooks. Traditional mathematics classrooms tend to focus on the teacher as the disseminator of knowledge and on competitive classroom environments. Recent research, however, provides evidence that women prefer, achieve higher, and demonstrate more confidence in mathematics classrooms that use project-based curricula and cooperative learning strategies rather than individualized and competitive teaching techniques (Becker, 1995, 2003; Boaler, 2002). Therefore, curriculum and classroom environments may not only be affecting women's appreciation of and confidence in mathematics, but may also be influencing women's achievement within the discipline.

While the literature is abundant with possible reasons as to why women opt out of mathematics, much less work has been done exploring why certain women choose to enter mathematics-based careers. In a study of graduate students in mathematics and computer science, Becker (1990) found that the women and men in her study had similar reasons for enjoying mathematics and had similar academic preparation, however, the women in her study described less-purposeful reasons for attending graduate school. Furthermore, Becker (1990) found that most of the women in her study began excelling at mathematics at a young age and spoke frequently about the influence of one or more mathematics teachers who had encouraged them to study mathematics or computer science at the undergraduate or graduate levels.

In a study of 15 women who had careers in the areas of mathematics, science, and technology, encouragement given by teachers and family members played a prominent role in these women's decisions to enter mathematics-based careers (Zelden & Pajares, 2000). Neither the gender of the teacher nor the relation of the family member affected the strength of the influence. Furthermore, these women described themselves as needing to be "persistent" and "resilient" (pp. 233–234) in order to overcome the academic and social hurdles they faced as women entering male-dominated careers.

Ultimately, a substantial number of women currently study mathematics at the undergraduate level, however, a disproportionate number of these women do not choose mathematics-related careers (NSF, 2004). While studies have found that the encouragement of others, particularly teachers, was critical in these women's decisions to enter graduate programs and careers in mathematics-based fields (Becker, 1990; Zelden & Pajares, 2000), this does not necessarily explain why such a large percentage of women who choose to study mathematics at the collegiate level do not pursue careers in mathematics. The study presented in this paper takes an initial step at addressing this question. By contrasting the images of mathematicians held by undergraduate women mathematics students with the personality traits that they identify with, this work supports an emerging theory that suggests that such a dissonance may deter mathematically talented women from entering the field of mathematics.

2.1 Identity as a theoretical lens

Many scholars in the fields of sociology and education have studied the impact of identity and identity formation on the academic achievement and professional choices of students. The term *identity formation* "refers to the development of a sense of self, including the self situated within broader social contexts" (Riehl, 2008, p. 50). Therefore, the formation of one's identity does not occur in isolation. Rather, it is developed through complex negotiations of self, others, and society's expectations (Johnston & Swanson, 2007). Throughout schooling years, young people begin to form their identities with respect to academics, gender, and racial-ethnic groups (Riehl, 2008). These identities develop as a result of their interactions, relationships, and life experiences, both in and out of school (Stokes & Wyn, 2007). It is common for adolescents' identities to be further influenced by their peer groups and participation in extra-curricular activities (Guest & Schneider, 2008). One's identity, however, is not predetermined or static. As such, one's identity continues to be modified with new experiences and in different contexts (Gee, 2000–2001).

Scholars in science education have begun exploring the notion of one's science identity in understanding the experiences and persistence of women and students of color in the science fields. Carlone and Johnson (2007) have developed a framework in which they describe a student's science identity as consisting of three overlapping dimensions: competence, performance, and recognition. The dimension of *competence* entails the person's knowledge of science content. The category of *performance* encompasses the knowledge of the social norms and practices of scientists. This category tends to be more publically visible than the first. The final dimension is *recognition*, which involves recognizing oneself as a "science person" and being recognized by others as such. Furthermore, Carlone and Johnson (2007) see the construct of one's science identity as being highly influenced by one's gender, racial, and ethnic identities.

Other scholars, however, have determined that one's academic identity (in particular, mathematics identity) can also influence one's gender identity. Pronin, Steele, and Ross (2004) found that women in mathematics, as compared to their peers, often rejected "feminine qualities" that are considered to be negative within quantitative-based fields (such as having a feminine appearance, being emotional, and the desire of having children) but found no disassociation with "feminine qualities" that are unrelated to their success in quantitative fields (such as demonstrating empathy, sensitivity, or fashion sense). These scholars argue that the women in their study have "bifurcated" their feminine identities; in other words, they removed from their identities any feminine traits that they felt would be considered a threat to them as a successful woman in mathematics. Such "bifurcation" of these women's feminine identities presumably has allowed them to reconcile otherwise potentially conflicting identities (as a woman and as a successful mathematics student).

This paper explores another aspect of the role of identity in the participation of women in mathematics, that is, how they identify (or do not identify) with perceived traits of mathematicians. For the sake of this paper, I am purposely choosing to leave the definition of mathematician vague. I want to build from who the participants consider to be mathematicians and not impose my own definition upon them. For example, the National Science Foundation and the National Center for Educational Statistics do not consider elementary or secondary school mathematics teachers as having mathematics-based careers. If the participants in this study, however, consider people who hold such positions as being mathematicians, I do not want to exclude these positions from the discussion.

3 Research questions

The research questions that I intend to address in this paper are:

1. What characteristics do women mathematics majors associate with mathematicians?
2. Do women mathematics majors identify with becoming a mathematician?
3. How do the characteristics that these women attribute to mathematicians relate to their personal identities?

4 Methods

The data presented in this paper were collected as part of a larger study conducted during the spring of 2003 at a large public university in the Southwestern United States. The participants were all students enrolled in the same upper-level mathematics course. The course is what is often referred to as a "transitional course" because the class is used to help mathematics students transition from lower-level, computationally based mathematics to more advanced, theoretically based mathematics. The primary purpose of the course is to teach students how to write mathematics proofs and interpret formal mathematical language; the actual mathematical content of the course is considered to be secondary. At this university, this course is required for all mathematics majors and is an elective for mathematics minors. On the first day of class, the primary instructor of the course explained to the class that he believed this course was about learning the "secret handshake" of mathematicians. Throughout the semester, the instructor continued to maintain this atmosphere in the class by frequently reminding the students that he believed his purpose, as the instructor of the course, was to train them to become mathematicians. This perspective on transitional courses is not unique to this particular instructor. Similar sentiments can be found in the preface of Hale's (2003) textbook written for transitional courses. Because the students enrolled in this class were frequently told that they were learning to become mathematicians, this made them appropriate participants for this study.

The participants for the study were volunteers who were recruited via an announcement made mid-semester in their transitional course. The course consisted of approximately 30 students (half male, half female). Five women volunteered to participate in this study. All five of these participants were in their early to mid-twenties. Four of them were traditional students; the fifth had spent four years in the military before attending college. Four of the participants were Caucasian and one was of Asian descent, however, all five of them grew up in the Southwestern United States. All of the participants had junior class-standing and had completed between four and seven mathematics courses at the collegiate level. The participants were fairly average students in the class; none of them were at the very top of the class, yet none of them were at the bottom either. At the beginning of the semester, all of the participants were declared as mathematics majors. During the semester of the study, however, one of the participants changed mathematics from being one of her three majors to being a minor. Three of these women were earning a degree in mathematics education though only two of them were intending to go into the field of teaching.

As a member of the teaching team for the course, the researcher knew the students in this study and had built a rapport with them throughout the semester. Often acting as a mentor or advisor to many of them, the researcher had built a trusting relationship with the participants prior to the collection of data (Rossman & Rallis, 1998). Despite being a member of the teaching team for this course, the researcher had no influence on any formal assessment of the students or on course grades. This was to help alleviate the possibility of students feeling coerced to participate in the study.

Individual, semi-structured interviews were conducted with each of the participants. During the interviews, these students shared their mathematical life-histories and their future career plans, as well as their beliefs about mathematics and mathematicians. Each interview lasted between 45 min and an hour and a half. The questions used to guide the interviews can be found in Appendix A.

The interviews were audio-recorded, transcribed, and analyzed inductively. Therefore, I did not approach the data with a set of hypotheses to test or with categories developed in another context. Instead, the codes were developed from and grounded in the data itself (Strauss & Corbin, 1998). I began by reading the transcripts and developing initial codes for beliefs about mathematicians based on the dominant themes that arose from the interviews. After tentative categories were formulated, the interviews were reread and the codes were refined as necessary. Once the final set of codes were developed, I recoded all interviews accordingly. Finally, I reread the transcripts once again and coded for participants' beliefs about themselves with respect to the characteristics expressed about mathematicians. Pseudonyms have been assigned to each of the participants in order to protect their anonymity.

5 Results

The original intent of this study was to investigate how undergraduate students view mathematics as a discipline after taking their first proof-based mathematics course and how their prior mathematics experiences influenced their beliefs. During the analysis of the interviews, however, unexpected themes emerged. I found numerous similarities amongst these students' responses with respect to their comments about mathematicians. Furthermore, I noted consistent dissonance between the students' comments about mathematicians and their self-reflective remarks about themselves.

While discussing their beliefs about mathematicians, the participants in this study shared a number of personality traits that they believe mathematicians often possess. Patterns emerged from their responses and were classified into three over-arching categories. These women saw mathematicians as: (a) extremely intelligent, (b) obsessed with their work in mathematics, and (c) not fitting in with social norms. While none of these traits is completely independent of the others, I found that each of these categories deserved separate attention. In the following sections, I provide descriptions of who these women classify as mathematicians and expand on these women's beliefs with regards to each of the aforementioned themes. I then present mini-portraits of each of the participants (Rossman & Rallis, 1998) describing their beliefs of themselves with respect to these traits.

5.1 Beliefs about mathematicians

Despite the fact that the women in this study were majoring in mathematics, they found it quite difficult to come up with a definition for the term "mathematician." After much consideration, however, they each proposed a definition that they deemed suitable. The following examples are representative of their responses:

> Someone who focuses on math, and math specifically. (Cathy)
>
> I want to say an expert in numbers. But… I don't think that would cover it all… Someone who is very knowledgeable of. Someone who has a dissertation, who has a doctorate in mathematics. (Laurie)
>
> When I picture a mathematician, it's somebody who not only enjoys math, but does it for a living… A mathematician isn't somebody who just dabbles in math in their free time. (Megan)

In order to gain a better understanding of who these students classify as mathematicians, three of them (Cathy, Laurie, and Helen) were asked to describe the types of jobs they envision a mathematician having. These women demonstrated frustration and slight embarrassment for having such difficulty coming up with possible careers that a mathematician might have. Although they initially suggested careers such as professor, teacher, and researcher, these women were unsatisfied with having only these careers to classify all mathematicians. Though they tried to expand their list of possible careers for mathematicians, the only other occupations that these students collectively offered during the period of the interviews were: accountant, stockbroker, someone who works with computers, and someone who does probability for casinos.

Whereas the women in this study found it difficult to define the term “mathematician,” they easily came up with a number of personality traits they believe mathematicians possess. The most frequently shared personality trait believed of mathematicians was that mathematicians are exceptionally intelligent people. Some of the most common words or phrases they used to describe a mathematician were: “knowledgeable,” “logical,” “theoretical,” “a thinker,” and “uses sophisticated language.” These women talked about mathematicians as people who do not just accept knowledge, but people who constantly challenge ideas. As Cathy expressed, “I think they challenge a lot more. They think a lot more.” Both Laurie and Megan identified mathematicians as being philosophical.

These students also saw mathematicians as talented problem-solvers. Dana, when describing a mathematician commented, “I think a mathematician could, when given a problem, go away for a while and come up with either ‘That’s not possible’ or ‘Here’s your answer’ or, ‘Use these two things and you’ll get it’.” Another student, Helen, claimed that mathematicians are not simply problem-solvers, but are always searching for new ideas and more knowledge:

> When I think of a mathematician, I think of a person who’s more than just knowing how to solve problems… Like, I feel like you don’t stop [learning] after you become a mathematician. Really you are still doing more to it—to learning, exploring, increasing your knowledge.

Along with being very intelligent, these students shared a belief that mathematicians are often obsessed with their work and with mathematics in general. They pictured mathematicians as always being in their offices, hard at work. When describing why she sees one of her peers as being a future mathematician, Laurie claimed, “You give him a problem and he’s just like at it… He just takes it seriously and he will solve that problem before he falls asleep.” Whereas Laurie believes mathematicians lose sleep because of their work, Megan insinuated that these two things, sleep and work, can describe a mathematician’s entire life by saying, “[Mathematicians] are either hard at work or sleeping.” Helen and Dana also described mathematicians as spending long hours working on mathematics.

The final quality that these women believe mathematicians to posses is that they are misfits in society. They often described mathematicians as being abnormal, eccentric, and bizarre. Cathy summed up many comments made by these students by saying, “I don’t want to define normal, but [mathematicians] are just *different*.” This belief ties in directly with the first two personality traits previously mentioned. People who are unusually intelligent and are passionate about mathematics are often seen as not fitting in with the norms of society (Damarin, 2000).

Though Cathy claimed that a typical mathematician is “different,” she said she views mathematicians as being outgoing. This belief was not commonly held amongst the participants, however. Three of the students specifically talked about mathematicians as being introverted. Laurie referred to mathematicians as often being isolated and not very sociable. Dana went as far as to refer to mathematicians as hobbits:

> Mathematicians always work alone in my mind. They’re always like those, those hobbits that live in their own little room… Like this would be perfect,[3] lined with grease boards and chalkboards. That would be a mathematician’s office.

Helen appeared to have a similar picture in mind. Helen claimed that she believes mathematicians “spend lots of time in [their] room, with a chalkboard and a paper and a pencil.” When asked, “Would you see them alone in the room or working with other people?” Helen firmly responded by saying, “Alone. Definitely alone.”

These last two comments refer not only to the belief that mathematicians work in solitude, but also to their work environment. These women seem to suggest that chalkboard-lined walls are necessary for a mathematician’s work. Furthermore, Dana’s comment that the deserted office fits her mental image of a mathematician’s office further suggests that she sees a mathematician’s office as not having anything else in it other than what is needed to get work done.

5.2 Beliefs about Themselves

While telling of their mathematical histories, the women in this study provided insight into their beliefs about themselves as mathematicians. Furthermore, each student was

[3] Dana is referring to the room the interview was conducted in. This room was a deserted office that had a bookshelf full of books, a table with two chairs, and some cardboard boxes on the floor. There was a chalkboard hanging on one wall. There was nothing else in the room.

directly asked if she thought of herself as a "mathematician-in-training." In the form of mini-portraits, I will share each woman's beliefs about herself with respect to the personality traits these women believe mathematicians to possess.

5.2.1 Helen

When asked whether she sees herself as becoming a mathematician, Helen responded by saying, "I think I'm going to but I can't say. In my mind, I want to [become a mathematician]."

At the time of the interviews, Helen was in her third year at the university and was intending to graduate within 2 years. Being the first in her family to attend college, Helen had little guidance from family members when choosing her major or future career. After being inspired and intellectually challenged by a mathematics professor during her first year of college, Helen decided to study mathematics. She chose to earn a degree in secondary mathematics education.

During the interview, however, Helen admitted that she was not sure that she was interested in teaching high school. Rather, she wanted to do research in mathematics. She had begun thinking about going to graduate school to earn a master's degree in mathematics, but she confessed that she was afraid that it was something she could not accomplish. "I'll see how it goes. That's something I want to do. If I could, I would… Cause I've heard all the exams are so scary. I just don't know if I'll be able to go through that." Helen even talked about being too scared to apply for graduate school, saying that she was afraid that there might be some sort of entrance exam that she would have to take.

Helen expressed a strong desire to become a mathematician and to do research in mathematics; however, she also expressed her belief that such a goal may be out of her reach. Helen struggled with the transition from high school mathematics to college mathematics and now views mathematics as a difficult subject. Due to the fact that Helen believes that mathematicians are unusually intelligent, Helen doubts herself in achieving her goal of becoming a mathematician.

5.2.2 Cathy

Cathy earned an associates degree by going to night school during the four years she served in the Military. At the time of the interviews, Cathy was pursuing a bachelor's degree in secondary mathematics education, and was intending to teach mathematics at the high school level. When asked if she viewed herself as a mathematician-in-training, Cathy first paused and then answered by saying:

> Yes. And I say that because I'm really for people thinking of teaching as a profession. Because a lot of people do not think of teachers as professionals. They're just teachers. I don't know why. It's not the same as being an accountant or a physician, or, whatever. You know, so. I think it's important to think of myself and other [mathematics teachers] as mathematicians.

When asked, "Thinking back on your high school math teachers, do you think of them as being mathematicians?" Cathy replied by saying, "No. Isn't that sad?" Cathy continued by claiming that she believes it is important to think of mathematics teachers as mathematicians, and therefore she should consider herself as one too, but she appeared to be still trying to convince herself of this.

Throughout the interview, Cathy often talked about struggling with mathematics and claimed that she is not very good at mathematics. This had not always been her belief, however. At one point Cathy admitted, "I thought I was good in it in high school, but I was also on the low track. I never took calculus [in high school]." When Cathy refers to the "low track," she is actually referring to the standard curriculum, yet since so many of her college peers had been in an accelerated mathematics program in high school, Cathy now considers the standard curriculum as a decelerated program. She even commented that her mother jokes with her, questioning her why she is studying mathematics when she finds it to be such a difficult subject. Cathy claimed that the reason she chose to study mathematics was "because I always enjoyed it, even though it's hard."

5.2.3 Laurie

Laurie's response to the question of seeing herself as a mathematician-in-training was, "Heck no!" She then continued to explain, "I don't have the brain structure for a mathematician."

Laurie is a strong student in all subject areas and has been throughout her schooling years. Laurie described her high school experience as being pushed to excel by teachers:

> In high school where they kind of push some people and didn't push others, I was one of those who got pushed… They put them in gifted classes and they usually push in all areas. And so math was one of those. So I took calculus when I was a junior in high school.

Besides crediting her scholastic success to being encouraged by her teachers, Laurie specifically credits her success in computational mathematics to having learned to play the piano at a young age. She believes, however, that because playing classical music does not involve creativity, she is not creative enough to do abstract mathematics, and therefore does not have the "brain structure" to be a mathematician.

Laurie also claimed that she does not consider herself to be a mathematician because, "I'm not like gung-ho!… I don't think I'm that hard core." Laurie contrasted herself to a peer of hers who takes mathematics very seriously and becomes fixated upon a mathematics problem until he is able to solve it. She explained, "I'll work hard at it, but it's not the end of the world, you know." While Laurie enjoys mathematics, she admitted that she likes variety in her life. Laurie spoke frequently of her other interests and her plans to travel abroad to teach.

I also found it interesting that during the course of the interview, Laurie commented that many of her peers have suggested to her that she does not fit the image of a "math person":

> This has happened to me quite a few times. I mean, I'm not a mathematician, but just the fact that I'm studying math as part of my studies, a lot of people when I first meet them, they're like, "Oh you study math" and they look at me and they… It's as if I don't fit like what they're thinking of a mathematician or a math person. I mean, I've had very strange comments. Like one time it was like, "You're too pretty to be [a math major]." And I'm like, "What does that have to do with it?" And it just doesn't fit. I don't know. But like maybe I'm really, maybe more talkative than they would think [a math person would be].

Laurie's experiences suggest that not only do the women in this study hold such beliefs about mathematicians, but that they are aware that others also hold these beliefs as well. When interacting with others, it appears that Laurie often needs to justify her identity as a mathematics major with other qualities she also identifies with.

5.2.4 *Megan*

Megan, thinking some day she may work for the CIA (Central Intelligence Agency) or the NSA (National Security Agency), answered the question by saying, "I feel like I'm working towards that goal," but made it a point to include, "I don't think that would be the only thing that would define me as a person, as like I'm just a mathematician."

Megan mentioned that she sees mathematics as being an integral part of a mathematician's life, so much so that sleep is the only thing mathematicians allow to interfere with their work. While Megan would like mathematics to be a big part of her life, she also made it clear that she does not want to be seen as simply a mathematician, but wants to have other things in her life as well.

Megan, like Laurie, was a strong student in all disciplines in high school. While she remembers being one of the top students in mathematics, she had other academic interests as well:

> I surprised my entire family when I picked math. I was really involved in the yearbook in high school and also I did really well in my English classes and stuff and so everyone thought I was going to do English or Journalism or something. And I said math and they were like, "Where did that come from?"

Though she did not pursue Journalism in college, in addition to studying mathematics, Megan was earning minors in computer science and in Japanese.

5.2.5 *Dana*

Initially, Dana was triple-majoring in biology, biochemistry, and mathematics. Feeling overwhelmed with completing three majors, during the semester of the study, Dana changed her mathematics major to a minor. Therefore, her response to whether she viewed herself as a mathematician-in-training was, "I suppose not, really. I'm a little more of a scientist than a mathematician."[4]

When asked during the interview about plans after college, Dana responded by saying that she was considering either entering the field of forensics or becoming a mathematics teacher at the community college level. After the interview was officially over, however, Dana began discussing her future again and admitted that she would like to be a stay-at-home mom and home-school her future children.[5] She claimed that she would always want to have a "job on the side" though. Dana provided the possibility of doing secretarial work as a type of job that would fit her future needs.

Though Dana claimed that she views herself more as a scientist than a mathematician, she does not picture herself having a career in science either. Rather, Dana would like to have a career that is not very time-consuming and that would allow her to have ample time to play a large role in her future children's lives. It appears that Dana believes that jobs involving science or mathematics must necessarily be demanding. It is possible that this is a reflection of

[4] Despite her change of degree, I found it relevant to include Dana in this analysis because many of the stereotypes of scientists are similar to those of mathematicians (Finson, Beaver, & Cramond, 1995; Huber & Burton, 1995).

[5] Dana was engaged to be married a few months after the interview took place.

her belief that mathematicians (and possibly scientists as well) are obsessed with their work.

6 Discussion

The women in this study shared common beliefs about personality traits they envision mathematicians to possess. I have classified these traits into the following three categories: (a) mathematicians are extremely intelligent, (b) mathematicians are obsessed with their work in mathematics, and (c) mathematicians do not fit in with social norms. Although this study is based on a small sample and more data from a larger sample size is necessary to allow for generalizability, it is important to note that the images of mathematicians held by these women appear to align with many of the beliefs Picker and Berry (2000, 2001) found amongst middle school students. Many of the students in their study portrayed mathematicians as being unkempt (unshaven beard, dirty uncombed hair), lacking fashion sense (out of style clothes, mismatched clothes), having no friends or social life, and always with pens in pocket, prepared to work on mathematics. These depictions relate mathematicians to being social misfits and obsessed with mathematics. Furthermore, nearly 25% of the United States participants referenced Albert Einstein or drew Einstein-like characters. Such references to Einstein indicate a belief that mathematicians have a genius level of intelligence.

Damarin (2000) explains what she believes to be society's view of mathematicians by situating it in the framework of considering the "mathematically able" as a marked category, a term used in sociology, cultural studies, and other related fields to refer to a group of individuals viewed as being deviant from the norms of the popular culture. Because members of marked categories are seen as socially atypical, they are generally believed to be unable to engage appropriately in social interactions and often find themselves harassed or teased by those who are not members of the group.

One window into a culture's beliefs is to view the workings of the educational system. Although students who demonstrate difficulties learning how to read and write are seen as having "learning disabilities" and needing special assistance, students with difficulties doing arithmetic are simply seen as not being mathematically talented or as missing the "math gene" (Damarin, 2000). Often this is not viewed as a problem, but simply as something for that individual to accept. Not only has it become admissible in society for adults to struggle with mathematics, many adults proudly admit to this inability. This genetic view of the discipline of mathematics isolates the mathematically able as having an exceptionable level of intelligence and as being deviant from the norms of the culture.

Another glimpse into the beliefs of the general public is through the media. Damarin (2000) describes select items in the popular media such as books, magazine articles, and movies that depict both real and fictional mathematically talented characters. In each of these cases, the mathematically talented are seen as portraying at least one of the three traits described by the women in this study. In one example, a description of Dorothy Nelkin's account of the media coverage of Nobel Prize winners, these mathematically talented people are seen as encompassing all three of the aforementioned beliefs. In Nelkin's work, it is noted that the media coverage of Nobel Prize winners portrays them as being "socially removed" individuals. They are typically photographed standing alone, with nothing in the background but a chalkboard filled with complicated equations. Their actual scientific accomplishments are rarely discussed in the media, providing the perception that their work would be beyond the understanding of the general public. Moreover, from the quotes chosen by the media publishers, Nobel Prize winners are often portrayed as being obsessed with their work. Examples of this include comments made by these scholars that they intend to spend their winnings on expanding their laboratories.

Whereas the data collected for this study do not intend to show that these women's beliefs about mathematicians are formed by society's generalizations or by the media, a number of studies have documented the influence of the media on individuals' beliefs (for example, see Field, et al., 1999). Furthermore, in Picker and Berry's (2000) study in which they asked 12–13-year-old children to draw a picture of a mathematician, in four of the five countries, both boys and girls predominantly drew a male figure. In the United Kingdom, however, a substantial number of children drew Carol Vorderman, a former engineer who was starring in the popular television program *Countdown*. Therefore, it appears that this television series has played a predominant role in shaping/reshaping many of these students' images of a mathematician.

6.1 Contrasting these traits with the traditional "female gender identity"

Although three of the five women in this study answered affirmatively to considering themselves as future mathematicians, each one of them qualified their answer. Furthermore, each of the participants, while discussing their mathematical autobiographies, shared the firm belief that they do not exhibit at least one of the traits they associate with mathematicians, the first one (exceptionally intelligent) being desirable yet unattainable, and the other two (obsessed with mathematics and not fitting in with society) being unappealing altogether.

One may question, however, if the dissonance between these women's personal identities and what they believe it means to be a mathematician may be unique to women's experiences. Of course, it is likely that many men in mathematics may also experience such a conflict. I intend to argue, however, that the traits of mathematicians expressed by these women are more likely to cause tension with women's constructed identities as opposed to men's. Because one's identity is formed within a social context, the development of identity for women is, in part, affected by beliefs, expectations, and roles imposed on them by society.

The participants in this study did not consider themselves to be exceptionally talented in mathematics. While all of these women had identified with being a good mathematics student in high school, many of them had changed their belief as a result of their experiences in college. Although the women in this study saw mathematicians as often hard at work, they also described mathematicians as intrinsically talented in mathematics. By not seeing themselves as having this talent, many were unable to identify with this trait that they believe to be characteristic of mathematicians.

The women in this study are not unique in this sense; even the most mathematically talented women often report less confidence in their mathematical abilities than men (Adhikari, et al., 1997; Hargreaves, Homer, & Swinnerton, 2008). Furthermore, many women attribute their success in mathematics to effort and hard work whereas men are more likely to credit their success to ability (Jones & Smart, 1995). Therefore, if women view mathematicians as being intrinsically talented in mathematics, they are less likely to identify with this trait than men who hold these same views of mathematicians.

In contrast to the belief that mathematicians are obsessed with their work in mathematics, three of the five women talked about the importance of family and of having activities in their lives apart from work. Furthermore, all of them expressed interest in curricular areas other than mathematics. They demonstrated the desire to have a career that would not be overly demanding and in which they could utilize some of their other talents and interests apart from mathematics. These women viewed themselves as well-rounded individuals and did not want to deny their other interests. By holding the view that mathematicians are only interested in mathematics and dedicate their lives to the field, it appears that they view the career of a mathematician to be inconsistent with their future life-goals.

Kerpelman and Schvaneveldt (1999) have found that college students, both men and women, have already begun developing their identities with respect to both work and family, even though most college students do not yet have careers and are not yet married. Their data demonstrate that amongst those students surveyed, a higher percentage of women than men (79% as compared to 69%, respectively) were either family-oriented (i.e. placed a higher level of identity importance in their future parental and marital roles than their future career roles) or balanced-oriented (i.e. equally divided their identity importance amongst parental, marital, and career roles).[6] These results suggest that college women, as a whole, are already anticipating playing a large role in their future family life.[7] Furthermore, Johnston and Swanson (2007) discuss the tension that many women experience with respect to their worker-mother identity. These scholars argue that women with full-time employment who also embrace society's intensive mothering expectations[8] struggle to find a balance between their careers and their parenting responsibilities. Therefore, if mathematicians are believed to be obsessed with mathematics or mathematical careers are seen to be highly demanding, many women (as well as men) may be dissuaded from pursuing mathematics-based careers.

The final trait expressed about mathematicians is that they do not fit in with social norms. Whereas none of the women in this study specifically said that she did not associate with this quality of being abnormal, one could argue that by classifying mathematicians as "different," they view mathematicians as being different from themselves. Additionally, these women believed mathematicians to be isolated and to always work alone, yet they considered themselves to be social people and often worked with their peers on mathematics assignments, some of them claiming that working in their study groups was what they enjoyed most about their mathematics classes. Therefore, these women were unable to relate to the isolated lives that they believe mathematicians to lead.

Many characteristics that are traditionally labeled as "feminine" do not coincide with the traits of mathematicians. Some of these "feminine" characteristics, such as talking about relationships and talking on the phone (Pronin, et al., 2004), suggest that women are more concerned with social relationships than men are. Therefore, if women view mathematicians' lives and careers as being primarily isolated, then this may discourage them from identifying as

[6] The other two categories that students placed in were career-oriented and career/marriage-oriented.

[7] It is important to point out, however, that Kerpelman and Schvaneveldt (1999) noted large variance within gender groups and caution against making sweeping generalizations about each gender.

[8] Intensive mothering expectations include "self-sacrifice, a child-centered mom-identity, omnipresent accessibility, and mothers as the primary source of education, guidance and emotional sustenance" (Johnston & Swanson, 2007, pp. 453–454).

one and/or pursuing a career in this field. Furthermore, the comment that one of our participants received about being "too pretty" to be a mathematics major, further supported by the drawings of mathematicians constructed in Picker and Berry's (2000) study, also may insinuate a belief that mathematicians are disinterested in their appearance. Traditionally "feminine" qualities, such as being fashion conscious and wearing makeup (Pronin, et al., 2004; Riehl, 2008), however, suggests that women are often viewed as being concerned with their appearance. As such, women who do adhere to these traits may find it difficult to identify with the term "mathematician."

As I have argued, many of the traits that the women in this study have associated with mathematicians are traits that do not coincide with a woman's traditional "female gender identity." I am not claiming, by any means, that all women possess the characteristics of such a "female gender identity" nor am I claiming that men do not possess such traits. I am suggesting, however, that the image of mathematicians portrayed by the media and internalized by many through means of socialization causes dissonance with the traditional "female gender identity." Therefore, whether consciously done so or not, women who become mathematicians must either choose not to accept the stereotypical traits of mathematicians or choose not to identify with traits of their traditional "female gender identity."

Although the women in this study considered themselves to be "math people" as compared to the average person, they did not identify with characteristics they believe mathematicians to possess. In Carlone and Johnson's (2007) study of successful women of color in science, they found of the three dimensions of one's science identity (competency, performance, and recognition) that recognition seemed to play the largest role in whether or not these women experienced what they referred to as "disrupted science identities" (p. 1202). In their framework, recognition involves both the recognition of oneself and recognition by others as a "science person." Although the participants in my study recognized themselves as "math people," they did not identify with mathematicians. Therefore, in the use of this framework, it may be beneficial to distinguish between these two identities (a "math person" and a mathematician), at least for the field of mathematics.

Furthermore, I want to reiterate that the stereotypical characteristics of mathematicians, in general, are portrayed as negative images. It is also important to note that undergraduate science and engineering majors who hold positive images of scientists and engineers have stronger commitments to their major and to entering careers in these fields as compared to those students with more negative images of scientists and engineers (Wyer, 2003). Therefore, if images of mathematicians, and the ability to identify with such images, do influence mathematics students' career choices as well, it would be beneficial to find means with which to provide them with a more diverse view of the lives and careers of mathematicians than what is provided to them through the popular culture.

I would also like to suggest that it is also possible that dissonance between one's personal identity and the stereotypical traits of a mathematician could result in a form of stereotype threat. Although much of the literature on stereotype threat in mathematics explores this phenomenon with respect to either gender or ethnicity, it is possible that these other qualities associated to mathematicians may also create a form of stereotype threat amongst those who do not believe themselves to possess such traits. Therefore, even if the stereotype that mathematics is a male domain is dissolving, if the image of a mathematician does not also change with respect to these characteristics, people who do not identify with such traits may actually achieve lower in the discipline as a result. Research needs to be conducted in this area to test this conjecture.

6.2 Concluding remarks

The literature documents many reasons as to why women choose not to pursue careers in mathematics, such as lack of confidence, lack of support, and lack of interest. All of these reasons, however, are situated in a deficit model. The women are seen as lacking qualities that their male peers possess (Damarin, 1995). The results of this study, however, seem to suggest that another possible reason that women choose not to pursue careers in mathematics may be because of their beliefs about what it entails to be a mathematician. By believing that mathematicians possess these qualities, some appealing while others undesirable, these women do not identify themselves with mathematicians. Although it is possible to interpret the women in this study as also lacking mathematical confidence, I would like to suggest that this should not be the primary concern. Rather, by holding unusually high expectations for the intelligence of mathematicians, these women are placing mathematicians into an elitist category. It seems more suitable to address this notion as opposed to the one of confidence.

Whereas a number of intervention programs exist, some targeting pre-adolescent women (for example, Wiest, 2004; DeHaven & Wiest, 2003) and others focusing on undergraduate students (Gupta, 2005), none of these programs incorporate addressing women's beliefs about mathematicians. If it is the case that women's beliefs about mathematicians do indeed play a large role in their decisions not to choose mathematical careers, then effective intervention programs must include such a component. This may be as simple as having a mathematician as guest lecturer talk with the participants about such stereotypes and reassure them that one need not meet such criteria in order to become a mathematician.

No doubt, more research is necessary to explore the question of why so many women who major in mathematics often do not choose mathematical careers. Once this question is more thoroughly answered, we can then better determine what types of in-classroom activities or intervention programs would be appropriate to encourage women to pursue mathematical careers. Some preliminary implications of this study, however, may be to provide college students with information and awareness about mathematical careers and to present opportunities for women mathematics students to interact with mathematicians on a more personal basis. While it may appear to be an uphill battle with the opposing influence of the media, we must remember, these women have already chosen the field of mathematics. We simply need to encourage them to stay.

Appendix A: Questions used to guide the interviews

1. What is your major? Why did you choose this major? Do you have a minor?
2. Has this been your major since the beginning of your college career?
3. What year are you in school? When do you plan to graduate?
4. What do you plan to do after you graduate?
5. What do your family members do for a living?
6. Are any external forces (such as parents, spouse, friends) affecting your decision about your major? What about your post-graduation plans?
7. Where did you grow up?
8. When did you first become interested in mathematics? How did this come about?
9. Tell me a little about your mathematics experience in elementary school, in middle school, in high school.
10. Tell me about a good mathematics experience that you have had.
11. Is there another one you would like to share?
12. Tell me about a not-so-good mathematics experience you had.
13. Is there another one you would like to share?
14. What math classes (and other math-related classes) have you taken so far at the university level? Tell me a little about them. (Which was favorite? Least favorite?)
15. Have you ever seen or been asked to construct proofs before this class?
16. How do you feel about this class so far this semester? Has it changed since the beginning of the semester?
17. What expectations did you have coming into the course?
18. Is the course easier or more difficult than you expected? How?
19. How many hours a week do you spend on this class outside of class time?
20. How does this class compare to your other math classes? (difficulty level and content)
21. What do you feel is the purpose of this class?
22. What do you feel the professor wants you to get out of it?
23. What do you find most difficult about the class?
24. Is there anything that you find easy about this class? If so, what?
25. What do you feel is the purpose of proofs?
26. Do you think of mathematics as being created or discovered?
27. How do you think a mathematician would answer that question?
28. Define what a mathematician is, in your opinion.
29. Is there such a thing as a typical mathematician? If so, describe one.
30. Do you consider yourself to be a mathematician-in-training?
31. Are there any other thoughts you would like to share with me?

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