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# On the Persistence and Attrition of Women in Mathematics

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## Abstract

The purpose of this study was to investigate what motivates women to choose mathematics as an undergraduate major and to further explore what shapes their future career goals, paying particular attention to their undergraduate experiences and their perceptions of the role of gender in these decisions. A series of semi-structured, individual interviews were conducted with twelve undergraduate women mathematics majors who were attending either a large public university or a small liberal arts college. This study found that strong mathematical identities and enjoyment of mathematics heavily influenced their decisions to major in mathematics. At the career selection stage, these women desired careers that are service-oriented, social in nature, and involved mathematical applications. For those planning to become teachers, the desire to help others predominantly influenced their career decision. Many of the non-teaching majors were unaware of mathematical careers other than teaching that satisfied these career qualities. Implications of these results with respect to women's participation in mathematics are discussed.

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**Keywords:** *women; mathematics; career goals; undergraduate experience*

## 1. Introduction

Historically, there has existed a societal belief in the United States that men are naturally better at mathematics than women. In the early 1980s, a series of scholarly papers [7, 8] appeared to present scientific data to support this belief. These studies have been highly criticized, however, based on the fact that they did not utilize a representative sample [16, 37]. In more recent

years, large-scale studies have demonstrated that currently gender differences in mathematics achievement are virtually nonexistent. As is shown by the 2007 TIMSS study, while in some countries girls outscore boys in mathematics and in other countries it is reversed, the international average shows no gender differences in Year 4 and reveals girls outscoring boys by 5 points in Year 8 [64]. Specifically within the U.S., no gender gap in achievement exists at the elementary and middle school levels (grades K through 8) and is generally only found amongst the highest achieving students at the high school level (grades 9 through 12) [34]. Furthermore, men and women in the U.S. earn similar grades in equally difficult mathematics classes in college [12].

In addition to similar achievement, men and women in the U.S. study mathematics at comparable rates at the high school and undergraduate levels. In high school, effectively no distinction by gender is found amongst the advanced mathematical courses taken by boys and girls [38, 34]. Furthermore, at the turn of the century, undergraduate degrees awarded in the mathematical sciences (mathematics and statistics) had reached near parity between the genders, with women earning an average of 48.1% of these degrees between the years 1999 and 2001 [45].

Although women and men study mathematics at similar rates both at the high school and undergraduate levels, this pattern does not continue into graduate school and the workforce. During the same time span of 1999 to 2001, 43.5% of Master's degrees and only 27.3% of Doctoral degrees awarded in the mathematical sciences in the United States were earned by women [45]. Furthermore, in 2012, only 29% of full-time faculty in mathematics and statistics departments in the United States were women, and a bleaker number of only 14% of tenure-track faculty holding doctoral degrees in mathematics departments with doctoral programs were women [20]. This pattern is found in business and industry as well, with women constituting approximately 35% of those employed as mathematical scientists in 2010 [47].

Furthermore, it is interesting to note that in more recent years, some of these numbers have begun to decline. Between the years 2001 and 2009, the percentage of undergraduate degrees in the mathematical sciences awarded to women decreased nearly five percentage points, reaching as little as 43.3%, a low which has not been seen since 1982 [45]. A small decrease of approximately 2% can also be seen during that same timeframe amongst those earning Master's degrees [45]. Although there continued to be a slight in-

crease in the percentage of women earning PhD's in the mathematical sciences between the years 2001 and 2009, hitting a high of 33% in 2009 [17], by 2012 this number dropped two percentage points down to 31% [19]. At the moment, it is unclear whether or not these numbers will continue to decline.<sup>1</sup>

There remains a need in the United States for talented individuals, both men and women, to pursue careers in STEM fields [2, 38]. Although many students who are mathematically talented opt for other fields, women leave the field of mathematics at a higher rate than men [56]. In reflecting on statistics that show the percentage of women in mathematics begins to drop dramatically after the undergraduate level, it has been proposed by Lacampagne *et al.* that “something is happening in undergraduate mathematics to lead interested women out of mathematics” [38, page 241]. These scholars further comment, “Particularly missing in the research literature are reasons for women’s lack of persistence in continuing in mathematics from the undergraduate to the graduate program” [38, page 250]. Therefore, there is a need to study the population of undergraduate women mathematics students to learn what influences their decision whether or not to continue with a career in mathematics.

### 1.1. Theoretical Perspective

Some scholars have suggested biological differences as a main cause for gender differences with respect to mathematics achievement and participation [7]. More current research argues these theories to be unlikely, however, indicating that gender differences in both mathematics achievement and participation vary dramatically from culture to culture and have decreased substantially in recent years [29]. It is now widely suggested by scholars that social and cultural reasons are the cause for the distinction between the genders with respect to mathematics achievement and participation [22, 29, 59, 67].

When approaching this topic from a socio-cultural point of view, however, there continue to remain multiple perspectives. One such perspective is that of “the glass ceiling”, a metaphor used for the “unseen, yet unbreach-

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<sup>1</sup>It has been noted by Bressoud [10, 11] that the decline in percentage of women mathematics majors at the undergraduate level appears to be due to the fact that the sheer number of male mathematics majors is increasing at a faster rate than the sheer number of female mathematics majors. Furthermore, this growth in mathematics majors has occurred solely at universities with graduate programs in mathematics. The reason for these trends, however, is not yet known.

able barrier” that prevents women from being successful “regardless of their qualifications or achievements” [23, page 4]. Within this perspective, it is suggested that exterior barriers, in the form of discrimination, prevent women’s success in the field of mathematics [29]. In other words, women are being denied the opportunities for professional advancement.

Another socio-cultural perspective suggests that the under-participation of women in mathematics is a result of women’s choices. For whatever reason, women are *choosing* not to continue their studies in mathematics or are choosing not to pursue mathematical careers. While these choices may be based in part on one or more external constraints (such as discrimination, financial resources, informational resources, or racial, religious, or cultural beliefs), their choices may also be determined by their own personal beliefs and desires. Regardless of the influences, under this perspective, the decisions are seen as choices made by the women themselves. This perspective gives agency to women, viewing them as having control of their own educational and career decisions [21].

In this latter perspective, women are seen as active agents in their lives, as opposed to being passive participants. By considering the agency of women and their personal choices, this perspective also accounts for the reality that while some mathematically talented women find themselves leaving the field of mathematics, other equally talented women continue to pursue careers within the field. It is for these reasons that I have chosen to approach my work using this perspective.

### *1.2. Summary of the Mathematics Education Research Literature on Women in Mathematics*

When considering the persistence of women in mathematics, many scholars have noted the important role that support and encouragement of others plays in women’s decisions to pursue mathematics at the undergraduate and graduate levels [1, 28]. This encouragement most frequently comes from family members, teachers, and college professors and is cited as a prominent reason for women’s interest and persistence in mathematics. Similar results have been found amongst successful women in mathematics or science-related careers [68, 15].

Conversely, lack of mentoring by college faculty is a predominant reason women choose to leave graduate programs in mathematics [32]. Furthermore, at times, women report being treated as invisible or as if they do not belong in

the field of mathematics [4, 32]. Women also experience feelings of isolation when pursuing academic degrees in mathematics [4, 14, 31, 32, 60]. Hall [28] found that the undergraduate women in her study did not believe that they fit in with the other women mathematics majors. They viewed themselves as well-rounded and social, but perceived the other women in their mathematics classes as shy and “overly focused on mathematics” [28, page 374]. Hall [28] emphasized that it is not clear from her data whether the other women mathematics students really had such characteristics or if this simply was the perception of the women in her study.

Mathematicians, in general, are perceived as having similar personality attributes to those mentioned in Hall’s study. Piatek-Jimenez [50] found that undergraduate women mathematics students viewed mathematicians as exceptionally intelligent, obsessed with their work, and socially inept. Stage and Maple [60] noted that women graduate students described mathematicians as working in isolation and lacking social interactions. All of these attributes were seen as undesirable and incompatible with these women’s perceptions of themselves. Since individuals select potential careers based in part on whether or not they envision the career to be consistent with their self-image [3], it is possible that these perceptions of mathematicians deter women from entering mathematical careers.

Confidence in mathematical ability may also be a possible reason why women do not choose to pursue mathematics [35]. Women frequently report lower self-confidence in mathematics than their equally talented male peers [1, 4, 26, 33]. This trend is true even amongst the most mathematically talented students [30]. Furthermore, it has been documented that women more frequently attribute their success in mathematics to hard work and effort while men tend to attribute their success to ability [41].

The literature also suggests that many women may not pursue mathematics because they perceive mathematics as a masculine field [58]. Although historically mathematics has been viewed as a male domain, recent research proposes that this perception may be changing, at least amongst middle and high school students [24, 25]. Furthermore, Greene, Sullivan, and Beyard-Tyler [27] found that presenting career-based reading materials containing role models in non-traditional fields influenced high school students’ perceptions on the gendering of certain careers. These scholars propose that more interaction with non-traditional career role models may encourage greater changes in perceptions. Sharpe and Sonnert [57] provide a quantitative anal-

ysis in which they suggest this may be the case. These scholars noted that universities with a higher percentage of female mathematics faculty also have higher proportions of female mathematics majors. Their analysis shows a definite correlation, however, no causation could be implied by their work.

Though the perception of mathematics as a male domain may be changing, it has been suggested that the way mathematics is taught appeals more to boys than to girls. Mathematics is frequently taught using elements of competition, and those involved in competitive sports (more frequently boys) are more comfortable with the competitive nature of the mathematics classroom [66]. Girls often prefer to work in classrooms with collaborative and cooperative learning environments [5, 6, 26]. In recent years, technology has become more influential in the teaching of mathematics as well; however, technology-driven curriculum disadvantages women in mathematics [42]. Simon [58] argues that though women are now welcome in the field of mathematics, they must conform to the norms of the discipline that were historically created by men.

Although the literature is abundant with reasons why women choose to opt out of mathematics (attrition), much less is known about why certain women continue in the field (persistence). This current study was designed to contribute to both of these knowledge bases, with an emphasis on persistence.

### *1.3. The Current Study*

In this study, I have chosen to focus on women who have persisted with mathematics at the undergraduate level. The purpose of this study was to identify what inspired these women to choose mathematics as an undergraduate major and to investigate what factors influence their future career goals. Although this study began with four research questions (1–4 below), while analyzing the data I determined that a fifth research question was both relevant and interesting to this study. The five research questions that framed this study are:

1. Why did these women choose to major in mathematics?
2. What were their experiences as mathematics majors?
3. What influenced their future career goals?
4. How did the participants' perceptions of gender play a role in their mathematics experiences or decisions?
5. What are some personality attributes common amongst women who choose to major in mathematics?

## 2. Method

### 2.1. Participants and their Academic Institutions

The twelve participants in this study were undergraduate women mathematics majors at one of two institutions in the Midwestern United States. One of these institutions is a large, public university with approximately 20,000 students while the other is a small, private liberal arts school with approximately 1500 students. The large, public university offers Bachelor's, Master's, and Doctoral degrees in mathematics. At the time of the interviews, there were just over 30 tenure-track faculty in the Mathematics Department at this university, one third of whom were women. Throughout the past ten years, this university has graduated between 60 and 110 mathematics majors in one year, with an average of about 60% of the mathematics graduates being women. The small, private liberal arts school is strictly an undergraduate institution and does not offer any degrees beyond the Bachelor's degree in any field. At the time of the interviews, the liberal arts college had fewer than ten tenure-track faculty in the Mathematics Department and only one of them was a woman. This college has graduated between 5 and 15 mathematics majors in one year over the past ten years, with an average of about 40% of their mathematics graduates being women.

The women in this study were all U.S. citizens, had Caucasian heritage, and spent the majority of their childhood in the state where they were attending college. They all attended college immediately following high school and lived away from home during their college career. Each of the participants had either junior or senior class standing (generally third or fourth year of college) at the time of the interviews. All twelve of these students were majoring in mathematics; six of them were earning mathematics degrees to become secondary education mathematics teachers while the other six were earning non-teaching mathematics degrees.

These women were invited to participate in this study via email. At the small liberal arts college, all undergraduate women mathematics majors having junior or senior class standing were invited to participate. Four of the eleven (three non-teaching and one secondary education) were able to do so.<sup>2</sup> At the large, public university, given that the number of students who fit

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<sup>2</sup>Three more had shown interest but due to unexpected circumstances were unable to schedule interviews.



the desired qualifications would have resulted in too large a sample, I used a systematic random sampling technique when inviting students to participate in the study. I obtained the names of all students at this university who met the criteria of being a junior or senior level female mathematics major and divided them into two lists, those students earning a degree in secondary education and those earning a non-teaching mathematics degree. I invited all 13 students who were earning a non-teaching degree to participate in the study. I also invited every 5th student on the list of those earning degrees in secondary education, to make a total of 13 students from this category to be invited. Eight students (three non-teaching and five secondary education) from this university participated in the study.<sup>3</sup>

All participants were assigned pseudonyms. Participants with pseudonyms that start with a letter at the beginning of the alphabet (A–G) were earning degrees in secondary education. Those with pseudonyms that start with a letter from the middle of the alphabet (J–P) were earning non-teaching degrees. Table 1 below provides information about the participants.

Table 1: Description of participants in terms of major type, institution type, and career goals.

	<b>Major type</b>	<b>Institution type</b>	<b>Career goals</b>
Amy	<i>Secondary education</i>	<i>Large, public</i>	<i>Mathematics teacher</i>
Bonnie	<i>Secondary education</i>	<i>Large, public</i>	<i>Mathematics teacher</i>
Carol	<i>Secondary education</i>	<i>Large, public</i>	<i>Mathematics teacher</i>
Debra	<i>Secondary education</i>	<i>Large, public</i>	<i>Mathematics teacher</i>
Erin	<i>Secondary education</i>	<i>Large, public</i>	<i>Mathematics teacher</i>
Gina	<i>Secondary education</i>	<i>Small, liberal arts</i>	<i>Mathematics teacher</i>
Joan	<i>Non-teaching</i>	<i>Large, public</i>	<i>Social work</i>
Kelly	<i>Non-teaching</i>	<i>Large, public</i>	<i>Does not know</i>
Laurie	<i>Non-teaching</i>	<i>Large, public</i>	<i>Mathematician</i>
Mandy	<i>Non-teaching</i>	<i>Small, liberal arts</i>	<i>Does not know</i>
Nicole	<i>Non-teaching</i>	<i>Small, liberal arts</i>	<i>Does not know</i>
Paige	<i>Non-teaching</i>	<i>Small, liberal arts</i>	<i>Statistician</i>

<sup>3</sup>This particular university is well-known for its teacher education program and therefore the majority of the mathematics students at this university are studying to become teachers.

## 2.2. Data Collection

Each participant took part in a series of three 90-minute individual interviews. I used the interview technique known as in-depth, phenomenologically-based interviewing and followed the Three-Interview Series protocol as suggested by [55]. The first of the three interviews in my study focused on the participant's mathematical life history, prior to college. During the second interview, each participant shared her experiences thus far as a mathematics student at the undergraduate level. For the third interview, each participant reflected on the meaning of her experiences and discussed her future career and life goals. Each interview was audio and video-recorded, and all interviews were transcribed.

## 2.3. Data Analysis

Because the majority of the current literature focuses on attrition from mathematics rather than persistence, the few pre-existing themes in the literature for persistence were not sufficient to address the research questions. Therefore, I chose to analyze the data inductively. In other words, I developed my categories based on themes that I found emerging from the data itself [63]. To analyze the data in this large data set, I began by reading all three interview transcripts for each participant and bracketing paragraphs that I found to be important with regards to who this participant is or how she has experienced mathematics. I then began creating profiles for each of the participants, based on their mathematical stories shared during the interviews, as suggested by [55]. Once I created profiles for one-third of the participants, I noted themes that either spanned multiple participants or were crucial for one particular participant and began developing codes for these tentative categories. I then continued by creating profiles for the remaining participants, paying particular attention to already noted themes and to recognizing new themes. Using an iterative process, as I coded the profiles, I continued adapting my initial categories and creating new ones as needed until all twelve profiles had been initially coded. At this point, I refined and finalized my categories based on all the profiles. I then coded the data according to the final categories.

Focused analyses from this study have been previously published in prior articles. Piatek-Jimenez [49] discusses some preliminary results found among the participants from the large, public university, with an emphasis on their desire to have careers involving public service. Piatek-Jimenez and Alzaatreh

[52] emphasize the role that advising played in the academic decisions of the three non-teaching majors from the small, liberal arts school (Mandy, Nicole, and Paige). The findings presented in this current paper are a comprehensive analysis of the data from all twelve of the participants with regards to the research questions.

#### *2.4. Trustworthiness of Data Collection and Analysis*

Seidman's three-interview series protocol provides multiple features that enhance validity of the data. First, by having participants share their stories, it situates the participants' comments in context. Secondly, by interviewing participants over the span of multiple weeks, it accounts "for idiosyncratic days and [checks] for the internal consistency of what they say" [55, page 17]. Furthermore, by having a prolonged engagement with the participants, they generally develop a sense of familiarity and comfort with the interviewer, which allows the interviewer to explore more sensitive topics or topics from multiple angles. By interviewing multiple participants at an institution, it allows for participants' comments to be checked against each other for accuracy. Finally, this three-interview protocol provides the opportunity for informal member checking to occur during the second and third interviews.

In order to provide trustworthiness in the analysis of this data, I employed multiple triangulation techniques [43]. Participants' college transcripts and ACT scores were inspected to compare the participants' assessment of their mathematics abilities to their recorded academic achievement. The transcripts of the interviews were read and analyzed multiple times on many separate occasions to increase the reliability of the findings. Video-recordings of certain portions of the interviews were viewed during the analysis process to utilize participants' non-verbal communication when interpreting the meaning of critical passages. Field notes were also taken during the interviews and reviewed as an alternate source of data.

### **3. Results**

The five research questions will be addressed in this section separately, in the order that they were previously stated. In what follows, the direct quotes by the participants have been cleaned up. In particular I removed excess words such as "like" and "um" for the sake of readability. Whenever a participant emphasized a word or expression with the tone of her voice, I used boldface to demonstrate her emphasis.

### 3.1. *Choosing to Major in Mathematics*

Of the twelve participants, four chose to major in mathematics sometime during their first two years in college, seven made the decision while still in high school, and one had decided as early as eighth grade. When considering the reasons for their decisions, two predominant themes arose from the data: 1) these women have strong mathematical identities<sup>4</sup>, and 2) they enjoy mathematics. I will expand on each of these below.

#### 3.1.1. *Mathematical identity*

All the women in this study had strong mathematical identities, which they stated influenced their decision to major in mathematics. These mathematical identities were formed throughout their lives, generally beginning at a young age. Though none of the participants had officially decided to major in mathematics prior to eighth grade, a few of the women mentioned that they probably knew subconsciously from when they were young. As Kelly stated, “It was always my favorite subject so I just assumed I was going to major in it. . . I always knew that that’s kind of what I wanted to go into.” These women often described mathematics as “their subject” and claimed that mathematics was a strength of theirs. It is important to note, however, that these women demonstrated talent in multiple academic and non-academic disciplines; many of them graduated toward the top of their high school class and participated in activities such as music and sports.

Family members were cited as playing a large role in the development of these women’s mathematical identities. While all of the participants felt that the discipline of mathematics was viewed positively by their families, eight of the participants directly credited a specific family member for their interest in mathematics and six of these eight mentioned their father. Often, doing mathematics with their father was their earliest mathematics memory. As Bonnie fondly recalled:

*“I remember when I was a little kid I had these blocks. They were like geometric shapes, basic geometric shapes, of like triangle, square, circle. And my dad used to play with me with these*

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<sup>4</sup>Different scholars have slightly different definitions of the term “mathematical identity”. When I use the term “mathematical identity”, I am referring to a participant’s beliefs about her abilities in mathematics and her beliefs about the importance of mathematics in her life.

*blocks all the time. Me and my dad would play with these blocks when I was a little kid. And he worked really weird hours, so it was really important when I got to spend time with my dad. It's like, 'Dad's home. We're playing with the blocks.' Here I'd be in my little feety pajamas dragging them out at night, cause that's when he'd get home... And he used to always, you know, 'How many sides does this have? What is this? What hole does it fit in? Why is it different than this one?' And we used to talk about geometry."*

Through these six women's stories, it is clear that not only did their fathers specifically encourage them in mathematics, but having this time with their fathers was meaningful to them. Therefore, mathematics was used as a medium for strengthening their bonds with their fathers.

These women also stated that their academic achievement played a role in the development of their mathematical identities. All of the participants had been recognized as mathematically talented by their teachers by the time they were in middle school, though many of them were distinguished from their peers at a much younger age. They were given enrichment activities by their teachers, were placed in advanced mathematics classes, and were regularly asked by teachers to assist their peers. Furthermore, many of them received awards in mathematics or were invited to participate in extra curricular activities such as Math Olympiad or Math Teams.

Although receiving acknowledgment from their teachers helped strengthen their mathematical identities, just as important, if not more important, was the acknowledgment they received from their peers. Eight participants explained that their peers often solicited help from them in mathematics, which authorized them as a "math person"<sup>5</sup> amongst their peers. As Bonnie recalled from seventh grade, "I established myself as kind of a brain in that subject that year." Kelly described her ninth grade experience in Geometry class by saying, "I was the only freshman in [that class] ... and there were upper classmen in there and they used to call me a child prodigy! Just cuz I knew what was going on."

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<sup>5</sup>When describing themselves as a "math person" the participants appeared to be referencing the fact that they were good at mathematics. No fixed biological ability, however, is being implied through the use of this term.

This acknowledgment from their peers really strengthened their confidence in *themselves* in mathematics as well. In referring to her ninth grade mathematics class, Amy recalled:

*“I was getting to the point where I could start helping other people so that made me a little bit more confident. And people would rely on me and ask me for stuff like that, so I thought that that was kind of cool.”*

By the time these twelve students entered college, they were confident in their mathematics abilities and identified mathematics as a subject they excelled at. Table 2 is a summary of these influences on the participants’ mathematical identities.

	<b>Family Member</b>	<b>Academic Achievement</b>	<b>Peers</b>
Amy	<i>Brother</i>	✓	✓
Bonnie	<i>Father</i>	✓	✓
Carol	<i>Father</i>	✓	
Debra		✓	
Erin	<i>Father</i>	✓	✓
Gina		✓	✓
Joan	<i>Father</i>	✓	✓
Kelly	<i>Father</i>	✓	✓
Laurie		✓	✓
Mandy		✓	
Nicole	<i>Father</i>	✓	
Paige	<i>Mother</i>	✓	✓

Table 2: Influences on the development of the participants’ mathematical identities.

### 3.1.2. *Enjoying mathematics*

In addition to having a strong mathematical identity, eleven of the twelve women (all except for Mandy) stated that their enjoyment of the field played a role in their decision to major in mathematics. Some qualities these women reported liking about the field is that mathematics is logical, has a process, and is objective. As Kelly described:

*“I used to tell my mom when I was younger, she’d ask me, or someone would ask me, what my favorite subject would be, and I’d be like, ‘Oh, it’s math.’ And they’re like, ‘Well why?’ It’s like, ‘I like the way my brain works!’ That’s what I used to say. . . It’s just, I do. I like the way my brain works! It’s just analytical and it’s logical and it’s just fun.”*

Nine of the participants made analogies to mathematics being a game or a puzzle. Joan said, “It was just like a game, a puzzle. . . Just the whole process of it. It’s just kind of like a game to me.”

Another quality of mathematics that these students appreciate is the problem-solving aspect of the field. Mandy described it as follows:

*“It makes you think, and that you can’t always just find the answers by looking them up either. . . Like in math there’s more problems, and so you have to work through them to solve them. Where it seems like, in other disciplines, not so many. There’s not as many problem-oriented, it’s more questions and answers.”*

One thing that these women appreciate the most about learning mathematics is being able to apply it to other aspects of life. Nine of the twelve participants spoke about enjoying mathematics because of its real-world applications. This frequently occurred when they discussed good memories from mathematics classes. They shared favorite stories about a physics experiment in an Algebra class, using real-life data in a Statistics class, or learning an application to skiing in a Calculus III course. Bonnie shared a meaningful story of when she was able to use her geometry knowledge outside of the classroom:

*“I remember one of my most favorite instances from high school math was in my drama class. . . me and my group of friends. We’d finish early and we’d just kind of sit around and talk and stuff. [The teacher], you know, in an attempt to keep us busy, says, ‘Well I’ve got this oval shaped pool in my backyard and I feel like the contractor is kind of screwing me. I want to put mulch around the pool and I want it to go a foot this way and I need bricks and they are this long, and I need, you know, how much? And I want it to be 3 inches deep’ or something. And*

*she asked us about how much she would need. So we got out this book and we're looking at formulas for like the circumference of an ellipse and we figured it out. And the guy was overcharging her like 150 or 200 dollars. And it wasn't for labor. And so she called him up and made him change the estimate."*

This situation showed Bonnie how powerful mathematics can be. Bonnie went on to say that she recently saw this teacher again when she was visiting her hometown. The teacher actually reminded Bonnie of this story saying that she was so pleased that Bonnie and her friends were able to save her that money so many years ago.

In addition to specific properties about mathematics that they enjoy, these women shared other things that drew them to the field. Eight participants claimed one reason they like mathematics is simply because they are good at it. Seven stated that they genuinely find mathematics to be interesting. Seven talked about liking mathematics because it is challenging or because of the feeling of accomplishment they have when solving a difficult mathematics problem. In response to why she enjoys mathematics, Gina stated:

*"I enjoy the challenge and the rewarding feeling you get from actually conquering those challenges. I don't know. Math, it's just like that. It's one of those things where it just kind of eats at you if you can't get something, and so when you do get it, it feels pretty good."*

Six of the twelve participants also talked about liking mathematics because they like being able to do something that most people are not able to do. Three responded that what they have enjoyed most about their experience as mathematics majors is the reactions they receive when they tell people they are majoring in mathematics. These reactions suggest that they must be really smart. Bonnie also likes the prestige associated with the degree:

*"The prestige and stuff of the subject because it is difficult and some people do kinda shy away from it, and that kinda makes me feel like oh I've got a leg up on some people cuz I can do things that they can't... it's nice to feel good about something that not everybody is good at."*



Though some of the participants like mathematics partly because not many people study it, Kelly stated that she even likes the fact that not many women are in the field. She feels like it helps her stand out in a crowd. She does comment, however, that she has mixed feelings about this. She does not approve of the stereotype that women cannot or should not do mathematics and she believes that if there were more women in the field, it would help change this societal belief. Table 3 on the next page is a summary of what each participant stated she enjoys about mathematics.

### *3.2. Their Experiences as Mathematics Majors*

In general, these women enjoyed majoring in mathematics. Although each woman had a unique experience, certain themes spanned their experiences. I will first describe themes relating to their mathematics coursework and then describe themes relating to their social experiences as mathematics students.

#### *3.2.1. Coursework*

Even though the participants in this study came from two different institutions and were pursuing different types of mathematics degrees (teaching versus non-teaching), the required coursework for the different degrees was very similar; the number of credit hours and level of mathematics courses for all four degrees were comparable. The main distinction between the degrees is that the students earning degrees for teaching also needed to take a methods course in teaching mathematics. At the time of the interviews, all of the participants had junior or senior class-standing and all of the participants except one (Debra) had already completed the “Introduction to Proofs” course at their institution, as well as at least one other proof-based mathematics course.

When discussing the coursework for their major, six of the twelve participants talked about how time-consuming their mathematics classes were compared to their other classes. Many of the participants reported working on their mathematics assignments every evening of the week, often with their peers, in order to complete them. They explained that the assignments were both difficult and simply took a long time. Two of the participants commented that their mathematics assignments took longer than those in other disciplines because of the depth of understanding needed for mathematics. Kelly stated:

Table 3: Reasons for enjoying mathematics.

	Logical, objective	Game, puzzle	Problem-solving	Real-world applications	Good at it	Interesting	Challenging	Prestige
Amy	✓	✓		✓			✓	
Bonnie	✓			✓	✓	✓	✓	✓
Carol	✓	✓		✓		✓	✓	✓
Debra	✓	✓	✓		✓			
Erin				✓		✓	✓	✓
Gina		✓		✓	✓	✓	✓	
Joan	✓	✓		✓	✓	✓		✓
Kelly	✓			✓	✓		✓	✓
Laurie	✓	✓				✓		
Mandy	✓	✓	✓	✓	✓	✓	✓	
Nicole	✓	✓			✓			✓
Paige	✓	✓		✓	✓			

TABLE 3.  
*Participants' reasons for enjoying mathematics.*

On page 19 of:  
 Katrina Piatek-Jimenez, "On the Persistence and Attrition of Women in Mathematics",  
*Journal of Humanistic Mathematics*, Volume 5 Issue 1 (January 2015), pages 3–54.  
 Available at <http://scholarship.claremont.edu/jhm/vol15/iss1/3/>.

*“Being a math major’s time consuming. Cuz you can’t just memorize a list of notes; you actually have to understand how to do it and know why you’re doing it. So it’s time consuming. . . . Like history, or whatever, just memorizing, ‘Oh this happened in the Great Depression of 1929’ kind of thing.”*

Though their mathematics classes were demanding, in general, these women learned how to be successful in their coursework. It is interesting to note, however, that seven of the twelve participants mentioned at least one mathematics class where they felt that no matter what they did to study, they could not fully grasp the material in the course. This often caused emotions of frustration or defeat. For six of these students, the class they struggled with was either abstract algebra or advanced calculus, though for one student it was probability and statistics. Though these students expressed frustration with their experiences in these courses, they also recognized that they were not alone and that many of their peers were also struggling with the content in these same courses.

Another disappointment with their mathematics courses that many of the participants mentioned was that the instructors did not make connections between the material and other aspects of their lives. These women often did not know how or where the mathematics they were learning was applicable and therefore did not understand why they were learning it. Amy expressed her frustration as follows:

*“Some of the aspects where it **hasn’t** quite met my expectations is in that I don’t see its relevance. I think [abstract algebra] was a good class for that—that there was not a single real-life application in the entire semester. I mean it was all just, ‘Here’s a problem; do it.’ So that was kind of frustrating cuz it’s like, ‘Okay, well I don’t even know where I’m supposed to use this so **why** am I taking this class again?’ . . . It seemed like we were just doing math to do the math. . . . So that was kind of frustrating cuz it’s like people asking, like my boyfriend asking, ‘When are you actually going to use this?’ I honestly can’t tell you! I have no idea! But, so that’s kind of frustrating.”*

Not only did Amy feel frustrated herself, but she also felt embarrassed that she could not justify her discipline to her boyfriend, who was studying public relations.

One thing Joan hoped to gain from her major was to learn about the importance of the field of mathematics and to see the relevance of mathematics in her life. Joan's experience has been disappointing in this respect. She stated:

*“It seems to be getting so much more **magnified**, the deeper you go into it. But I was hoping it would get broader... It's hard to see the end result sometimes and that's what's frustrating to me. You know what you're supposed to do, but it's hard to understand why you're doing it or what the point of it is, and I think that that's what I was hoping to get out of my major in math, was to see a bigger picture of everything and incorporate it more into the way that I view the world. [With] other subjects, like English and history, there's a very direct correlation with things going on around you so it's easier to take that and apply it to your life, whereas math is very hard because it's all numbers. You don't see the end result of it... That's where you just are like, ‘This is stupid. Why I am doing this?’...”*

Since Joan's college mathematics classes have focused mostly on abstract theory and calculations, rather than real-world applications and connections, she struggled to see relevance of the content to everyday life and felt like her mathematics coursework was not helping her view the world from a more educated perspective, as she had originally hoped.

As previously mentioned, these participants greatly appreciated the real-world applications they learned in their K-12 education, but as they took more advanced mathematics classes in college, they felt that the applications and connections were becoming more and more sparse and they did not understand the relevance of their coursework. They were disappointed that, in general, their professors and their textbooks did not incorporate relevant applications into the courses. While they still found mathematics to be fun, they did not find the content to be meaningful. Table 4 on top of the next page is a summary of these participants' perspectives on their undergraduate coursework.

### *3.2.2. Social experiences*

One thing that many participants enjoyed about their experience as mathematics majors was the camaraderie that exists between the students in their

	<b>Time-consuming</b>	<b>Frustrating course</b>	<b>Lack of connections/applications</b>
Amy		Abstract Algebra	✓
Bonnie	✓	Abstract Algebra	✓
Carol	✓	Advanced Calculus & Abstract Algebra	
Debra			
Erin			
Gina	✓		✓
Joan	✓		✓
Kelly	✓	Abstract Algebra	✓
Laurie		Advanced Calculus	
Mandy		Prob. and Stats.	✓
Nicole			
Paige	✓	Abstract Algebra	

Table 4: Participants' perspectives on their coursework.

department. They always have someone who they can study with, call with regards to a homework question, or simply complain to when they are frustrated. Though most of the participants do not socialize with their mathematics peers on the weekends, they know where to find each other in the mathematics building on weekdays. The students who are earning a double major also noted the camaraderie that exists amongst students in the mathematics department is stronger than the camaraderie in their other major. They speculate this is partly because the mathematics degree is much more demanding than their other major, so they spend more time in the mathematics building and more time studying with and looking for support from their mathematics peers.

Another reason the camaraderie may be stronger amongst mathematics students is because of the isolation they experience outside of their department. Three of the participants spoke about their disappointment in not being able to share their discipline with their friends or parents. Carol described her experiences as follows:

*“It’s just really nice to have a community that understands what you’re going through almost. And with my roommates or anything, I’d be sitting there trying to explain something, like why I’m frustrated, and they’re like, ‘Carol, I don’t understand what*

*you're **saying**'. You know?... No one **gets** the math thing... They just smile and nod... My roommate who's a linguistics major, she can talk to me and it's easy to learn... And it's cool and it's fascinating and it's neat, cause it's something I can comprehend, but when I start talking about math, it's like people have this inhibition. And they're just like, 'You want to talk to me about math? No.' It's like they shut down right away. They don't even **care**... So it makes me feel like I can't really talk about my day... There's a feeling of solitude."*

Joan related her frustration of not being able to share her discipline with her parents to her similar frustration of not being able to understand the big picture of the field. She believes that if she could understand how the mathematics she is learning affects the world around her, then she would be able to build the bridge she needs to share her studies with her parents.

### *3.3. Influences on Future Career Goals*

I also investigated what these women's future career goals were and what influenced these goals. This is the only portion of the data where the responses and experiences of the six participants who were intending to become teachers differed slightly from the six who were not. As a result, I discuss these two different cohorts separately, where relevant.

Of the six participants who were earning degrees to become secondary school mathematics teachers, all of them intended to do so. The other six who were earning a non-teaching mathematics degree had a variety of career intentions (see Table 1). Paige was planning to earn a master's degree in applied statistics and Laurie was planning to earn a doctorate degree in mathematics. For careers, they intended to become a statistician and mathematician, respectively, working for either a company or for the government. The reason that both of these women chose to go to graduate school was because they believed that they would not be qualified for their desired line of work without a graduate degree. Kelly, Mandy, and Nicole had not yet chosen long-term careers. Joan had already decided to leave the field of mathematics to do social work for a non-profit organization.

In this section, I will begin by detailing what qualities these women were looking for in a career. I will then discuss their knowledge of possible career options and how this influenced their career decisions.

3.3.1. *Qualities in a career*

The most predominant quality that these women were looking for in their future career, mentioned by ten of the twelve participants, was to have a job that would allow them to help people. This was mentioned by all six participants who intended to become teachers. Bonnie explained her decision to become a teacher as follows:

*“I’ve always known that I wanted to teach, since I was like 8. . . I’m fascinated with how people learn. . . A lot of this comes from my mother too. She believes that everybody deserves the opportunity in America to have the basic skills that they need to succeed. And basic education. Basic math, basic everything, is so essential. You can’t make it without that kind of stuff anymore. . . I’ve always [wanted] to teach because I knew that everyone needed that and I felt like, ‘Oh I’ve got that, I can share that with someone else.’ You know?”*

Erin initially dreamed of becoming an aerospace engineer and using mathematics to design airplanes or sports cars but changed her career aspirations to becoming a teacher during her junior year of high school:

*“I guess it’s more of a moral thing. Like I went to the auto show, the Detroit auto show, last January when it was. I **love** those cars. **That’s** what I wanted to be a part of. I wanted to be a part of making that car. But, then I see like, what about. I see all the kids that are there and I’m like, ‘What about the kids’ education?’ You know? I mean I care about that more. That’s so much. I don’t want to promote something like owning a nice car. I mean, I’d rather teach people how to get a good education and make good decisions for themselves and inspire them and to challenge themselves. That is so much more important to me than a car. So that’s what changed my mind.”*

Although Erin demonstrated a strong passion for engineering, she also had a passion for helping people. When it came to deciding her future career path, her desire to help people took precedence.

The ambition to have a career in which they can help people, however, was not only mentioned by those wanting to become teachers, but was suggested

by four of the other six participants as well. This is such a strong requirement for Joan, that it caused her to choose to leave the field of mathematics altogether. As Joan explained:

*“If I were to [become a mathematician], it wouldn’t be satisfying to me. . . It doesn’t seem very rewarding or fulfilling. If you spend your whole life trying to come up with some new equation, it’s cool because you’re still doing something, but I don’t know. I need more of a reward than that. . . I guess knowing that you’ve helped like one person is like enough for me. . . Going into the non-profit is, for me, it’s like doing social activism. Trying to change the system, the standards. Trying to bring some sort of justice to people that deserve it.”*

Many of the participants also spoke of wanting a career that is social in nature. Six of the twelve participants (three teaching majors, three non-teaching majors) talked about wanting to work with people or have “human contact” or “public interaction” at work. Gina had considered becoming an accountant rather than a teacher but chose to become a teacher for the following reason:

*“I had to decide if I wanted to work with numbers or if I wanted to work with numbers and people. So I went more for the people. Just, I mean, there’s more variation on a day of teaching than there is on a day of crunching numbers.”*

When asked, Gina stated that if teaching were not an option for a career, she would have become an accountant.

Two of the participants specifically spoke about not wanting a career where they would be working at a computer all day. Kelly had initially wanted to become a cryptanalyst and work for the government to “help find terrorists,” but when she learned what this job would involve on a daily basis, she decided it might not be a good career for her:

*“[My professor’s] daughter came into our class. She works with the [National Security Agency], and that was something that I thought that I might want to do, and it’s not what I want to do anymore. . . She’s a cryptanalyst, and she’s behind a computer all*



*day in the office setting, and that's just not really what I want to do, but I would like to work for the government somehow using math, of course, but I don't really know what now, and it's just... another door was shut."*

While Paige does want a career where she works at a desk, she made a clear distinction between working at a company with offices versus one with cubicles:

*"I kind of want it to be a sort of desk job. Yeah, but not really my own office. I like the little cubicles... I don't like the offices because I feel like I'm shut off from everybody else. And I don't really like that. I like that interaction. Plus with cubicles it's really easy to have a short little 5-minute break talking to somebody else. I like those short little 5-minute breaks. That's one reason I like the cubicles."*

Among the five participants not planning to become teachers but wanting to stay in the field of mathematics, three of them talked about not wanting to do "pure mathematics" but rather wanting a career where they could apply mathematics to other fields. As Mandy stated, "I just like applying math to things. I don't want to do pure math... I want to apply my math skills to something bigger than math. So, to another field [such as] biology maybe." Table 5 on the next page is a summary of the qualities these participants desire in a future career.

### *3.3.2. Knowledge of career options*

Despite the fact that these women were earning undergraduate degrees in mathematics, none of them knew much about career options in the field. In fact, seven of the participants (including all six who were not intending to become teachers) responded to the question, "What obstacles, if any, are there for someone wanting to choose a career in mathematics?" with the fact that they do not know of many careers in the field. Mandy hypothesized that this may be a reason that more students do not major in mathematics:

*"I think if students as a whole knew more what they could do with math that there might even be more math majors cuz I know a lot of underclassmen will be like, 'Well, what are you gonna do with that?' and I was like, 'Hmm, I don't know.' And they might*

	Help people	Social career	Applied mathematics
Amy	✓		
Bonnie	✓		
Carol	✓	✓	
Debra	✓		
Erin	✓	✓	
Gina	✓	✓	
Joan	✓		
Kelly	✓	✓	✓
Laurie	✓		
Mandy			✓
Nicole		✓	
Paige	✓	✓	✓

Table 5: Desired qualities participants seek in a career. The shaded cells indicate that this choice does not apply to these participants.

*be considering a math major, but they're not sure what they can do with it either... I think sometimes with math, there's not a clear-cut, 'Well these are the careers you can take'."*

Two of the students even commented that they are sometimes embarrassed at family gatherings because extended relatives ask them what they plan to do with their degree and they do not really know what to say. Furthermore, many of the participants believe their degree in mathematics is somewhat limiting. Joan stated:

*"I mean, how many jobs are really out there for people who get math degrees? There's some, but it's not like. You know, it's very specific things you can do... You can't just get any job and use what you learned with your math degree."*

Although all of the participants knew they could become mathematics teachers, the six participants who were not studying to become teachers had all made a clear decision that they did not want to teach. Because they did not necessarily know what other careers were available to them, many took initiative to learn more about their options. Some of them spoke with their professors, attended talks, participated in an REU (Research Experience for

Undergraduates), or spent a day job shadowing someone in the field. Those who solicited advice from their professors expressed concern that their professors did not appear to know much about careers outside of academia either. In general, their professors simply encouraged them to participate in an REU. While Paige's REU experience confirmed for her that she would like to do statistical consulting for a living and Laurie's REU influenced her to want to do mathematics research, many of these types of experiences simply informed these women that they did *not* want a particular career. For example, Mandy's REU taught her that she did *not* want to do research for a living. Similarly, Kelly had job-shadowed her uncle, a banker, and had spoken with a young woman who worked for the National Security Agency, and both are now careers that she is no longer interested in obtaining.

At the time of the interviews, neither Kelly nor Mandy knew what career path they would like to follow. Despite their active attempts, neither had learned about a job that interested them. Since at the time of the interviews they each had another year or two of college before graduating, they both felt that they still had time before they would be forced to make a decision.

Nicole also did not know what career she would like to have, but because she was graduating that semester, she felt more pressed to make a decision. One day while she was on Facebook, she saw an advertisement for *Math for America*. This program would pay for her to move to New York City and earn a one-year Masters of Art in Teaching (MAT) degree, and then would require her to teach in the New York City School District for four years after completing her master's degree. Despite the fact that she had initially decided she did not want to teach, because she did not know of other options, Nicole chose to enter this program. Since the program did not require a teaching degree, she met the requirements. One thing she liked about the program was that it was only a five-year commitment, so she would not need to decide on a life-long career yet. This appealed to her since she did not know what career she ultimately wanted. Nicole specifically stated that she does not intend to be a teacher long-term. It appeared as if she was choosing this program as a way to delay deciding what to do with her degree.

Joan, on the other hand, chose to leave the field of mathematics altogether in order to pursue social work. She claimed that the only careers that one can obtain with a "straight up math major" is work for the government or be a professor and she does not find either to be appealing. Joan does not want to work for the government because she does not approve of the workings of the

government. For Joan, working for a non-profit is the complete opposite of working for the government. She sees working for a non-profit as taking part in social activism while working for the government as aiding in institutional injustices.

Though only one of the six participants earning a non-teaching degree had decided to leave the field of mathematics immediately following college, three of the six did not know what career they wanted long-term. They each were aware of a few careers available in the field, however, they did not find these careers appealing. Furthermore, they expressed concern that their knowledge of mathematical careers was limited and this lack of knowledge was an obstacle that they needed to overcome, but did not know how to do so. Table 6 summarizes the non-teaching degree participants' knowledge and experiences with non-teaching mathematical careers.

	<b>Knowledge of non-teaching mathematical careers</b>	<b>Means for learning about mathematical careers</b>	<b>Career goals</b>
Joan	Professor, Government work, Accounting	None (did not seek advice from professors)	Social work
Kelly	Banker, Actuary, Government work	Job shadowed banker (uncle) / Another uncle is an actuary / Talked with NSA employee (did not seek advice from professors)	Does not know
Laurie	Professor, Government work	Advising professors led to her REU	Mathematician
Mandy	Accounting, Business, Industry	Accountant parents / Advising professors led to her REU	Does not know
Nicole	None	Facebook advertisement (did not seek advice from professors)	Does not know
Paige	Statistical consulting, Industry	Advising professors led to her REU	Statistician

Table 6: Participants' knowledge and experiences with non-teaching mathematical careers.

3.4. *Perceptions of The Role of Gender on these Women's Mathematics Experiences or Decisions*

Overall, these women had very positive experiences with being a woman in mathematics. Many of them spoke about being encouraged to study mathematics by parents and teachers, specifically because they were women. As Debra explained:

*“They all thought it was good [that I major in mathematics] because I’m a girl. They were like, ‘You’ll be able to find a job really easily!’... My parents, my principal at school, lots of people told me that; that that was a good thing to go into.”*

A few of them even attended daylong events when they were young, designed to encourage women in mathematics. Carol attended one of these events in seventh grade and felt it was a changing point in her life:

*“At [university name], they have this push for girls in science and math and stuff. I went there for science, but I think I was recommended by my math teacher. So it was called girls + math + science... I think that’s like a big turn around of how I was trying to think. I think it was really beneficial for me. I wish more schools had it for high school [girls], especially in science and math... I’m really glad that I went.”*

Four of the participants even commented that they believe being a woman made it easier for them to enter the field of mathematics. They stated that because society is currently conscientious about wanting to diversify the workforce, they suspect they received more encouragement and more opportunities to enter the field of mathematics than they would have if they were a man. As Paige explained:

*“Being a woman helped with the REU selection... mainly because... there were definitely more males... So [the director] was definitely looking for more girls, and I think that’s what I mean. It wasn’t that I was under-qualified and being a woman just put me up there. It was the fact that out of all the candidates that were in my same position, I was the best choice... because he didn’t want another male.”*

Furthermore, these women believe it will be easier for them to find a job or be accepted to a graduate program in mathematics because they are women.

Despite the overwhelming encouragement they received, four of the women did recall at least one negative experience with being a woman in mathematics. Three of them remember being teased by their peers when they were young, either for being talented at mathematics or for being slow at computation. Two of them did not perceive these instances as being very influential; they viewed them as typical childhood teasing. The teasing that Carol received in middle school for being good at mathematics and science was more troublesome to her:

*“I just got picked on because I enjoyed math and science and I was a girl... I think for a while it was just like, ‘Well maybe I shouldn’t, maybe I shouldn’t be taking the upper level classes because I’m not meant to be there.’”*

In more recent years, all of the participants have received consistent support from their peers, both male and female.

Even though most of the participants received nothing but encouragement from their parents, teachers, and professors, two of the participants did have discouraging experiences with teachers. Kelly’s discouraging experience took place during eighth grade. She believed that her teacher did not give the girls in the class the same attention as the boys. Kelly recalled:

*“He didn’t have a lot of respect for the girls in the class. He just kind of wouldn’t help them as much as the guys... One time I went up there to ask him a question and there were a few students around me, and I think I was the only girl, or whatever, and I asked him a question and he would just be like, ‘oh just a second’ and then he’d just go to the guy. And then he would just kind of forget about me... I remember none of the girls in my class really liked him very much... The [other] girls and I, we would just talk about it a little bit. I mean, it didn’t make us too mad, but, I don’t know. We were young so... If I would have known back then really what he was doing, it would kind of discourage me a little bit, but I didn’t really. It wasn’t a big factor, I don’t think. It was just like, ‘Oh, okay, whatever. I get to talk to my friends when guys have to talk to the teacher.’”*

Though Kelly remembers this incident and spoke about it twice during the interviews, she claimed that it did not have a very big influence on her decisions later in life. Given that Kelly's father, grandfather, and three of her uncles all majored in mathematics, she had strong male support from her family and had already developed a strong mathematical identity by eighth grade, so the actions of her eighth grade mathematics teacher did not affect her perceptions of herself or of women in mathematics.

Carol also had a discouraging experience with a mathematics teacher, though her experience occurred during her senior year of college. Carol needed to take a specific mathematics course in a particular semester in order to graduate when she intended. She approached the professor prior to the beginning of the semester but he refused to bump her into the class. He argued that she would never be successful taking his mathematics class in addition to the other two mathematics classes that she had already enrolled in. Carol explained:

*“That was the first time I ever had a professor that was discouraging. Cause he’s like, ‘You can’t do it. You’re not going to do it. And, you’re going to turn stuff into me late and you’re going to expect me to have pity on you and I’m not going to.’ And I then told him that I’ve never turned any assignment in late—ever. Any of my academic career and I never plan to... I’ve never turned in a late assignment because I just don’t believe in turning in late homework, or assignments, or projects, or not preparing for a test. It’s something I just don’t believe in. And he didn’t believe me when I said that.”*

Carol was relieved when the semester began and a different professor had been assigned to teach that class. She approached the new instructor of the class and he was happy to let her take the course. In the end, Carol took the classes she intended to, passed them all, and never turned in one late assignment the entire semester. What bothered her the most about the situation, however, is that Carol had a male peer who was taking the same mathematics classes she was that semester, and the professor who refused to bump her into the class, bumped her male peer into the course. When Carol learned this, she was quite upset and felt that she was being discriminated against because she was a woman.

Because this incident occurred so late in her academic career, it did not affect any of the academic decisions that Carol made the rest of the time she was in college. This college experience and the teasing from her peers in middle school were not the only discouraging experiences Carol had though. She also repeatedly received discouragement from her mother who frequently told her that mathematics was too difficult of a field and that she should attempt an easier major. Carol felt lucky that both her father (who was no longer married to her mother) and her fiancé were both supportive with her decision to major in mathematics. These supportive figures were invaluable to her throughout her successful college career.

Though very few of the participants received discouragement from studying mathematics, all of them were aware of the historical stereotype that men are better at mathematics than women. Interestingly enough, however, Gina did not become aware of this stereotype until she reached college:

**Gina:** *I did have a professor here that told me that males tend to be better at the geometry kind of stuff, the spatial. Which I guess there's actually been research that men tend to be better at spatial representations. But up until she had said that I never thought about it. She made it seem like females were better at the English/language arts kinda stuff, and males were better at the mathematics/physics kinda stuff. . . And so I was kinda just like, 'Hey, um, I don't know what you're talking about, but I'm kind of a math major, so.' You know. . . according to Dr. B, we're about half and half for females to male as far as the math major goes. So I never saw that. So. . .*

**Interviewer:** *Did it bother you then, that she said this, or?*

**Gina:** *Yeah. Especially since in the class that she said that in, we had three math majors, and two of us were girls, and one was a guy. So we were kinda like, 'Uh, not really sure you know what you're talking about Dr. K,' kinda thing.*

**Interviewer:** *What was the point she was trying to make?*

**Gina:** *. . . She was kind of talking somewhat about the gender stereotypes and stuff like that, and talking about Asians with math and that kind of stuff. And she said, 'You know, you can't go with the stereotype.' But I was just really surprised that she said. . . a*



*stereotype that nobody else had apparently picked up on. So thanks for putting that in my head.”*

Gina had gone through her first 20 years of life without being aware of this stereotype, but unfortunately, in an attempt to combat the stereotype, her professor actually made her *aware* of it. Given that Gina is preparing to become a teacher, she expressed concern that knowledge of this stereotype may now subconsciously affect her future teaching.

Though most of the participants insisted they never experienced any sort of discouragement or prejudice from their mathematics teachers or professors, or even heard of anything like this happening at their schools, and they all specifically stated that they do not believe one gender is better at mathematics than the other, two of the participants did talk about their beliefs that men have an advantage learning from other men. As Erin explained:

*“I’ve taken sociology courses. I understand the dominant culture and the dominated cultures. And... I do think men and women do think differently, and when a man writes a test, and women take it and do badly, and men take it and think that they don’t know this stuff very well, but they still got a good grade, I mean... There are people out there that have studied this so much, how men and women converse, that they can read something and tell whether it’s a man speaking, writing this, or a woman writing this. Cuz it is **that** different.”*

Furthermore, both Erin and Mandy spoke about how male and female mathematics professors have different perspectives on a course and teach differently and claimed that they feel like they learn better from and respond differently to female mathematics professors. When asked, neither was able to provide specific details or examples; it was more of an overall impression they have.

### 3.5. *Personality Attributes*

Though the interviews were not specifically designed to access personality attributes, after speaking with each of these women for three to five hours apiece, many personality attributes could be noted throughout the interviews. While analyzing the data, I discovered some very clear patterns in the data with regard to these women’s personalities. Though these attributes did not directly address my original four research questions, I found them

worthy of discussion because they are all attributes that could assist women in choosing and being successful in the field of mathematics. Learning about such patterns in personality attributes may help the field better understand why certain women with similar experiences choose to persist in mathematics while others choose to leave the field. Table 7 lists the five reoccurring personality attributes found among the participants in my study and presents which participants portrayed each attribute.

	<b>Strong academic motivation</b>	<b>Competitive nature</b>	<b>Going against the grain</b>	<b>Self-sufficient</b>	<b>Not identifying with gender stereotypes</b>
Amy	✓	✓		✓	✓
Bonnie	✓	✓		✓	✓
Carol	✓	✓	✓	✓	✓
Debra	✓				
Erin	✓	✓	✓	✓	✓
Gina	✓	✓	✓		
Joan			✓		✓
Kelly	✓	✓	✓	✓	✓
Laurie	✓			✓	✓
Mandy	✓	✓	✓		✓
Nicole	✓	✓			
Paige	✓	✓	✓	✓	✓

Table 7: Personality attributes found among the study participants.

### 3.5.1. Strong academic motivation

All but one participant (Joan) demonstrated strong academic motivation. This motivation could be seen at both the high school and college levels. While in high school, these students completed many honors and A.P. (advanced placement) courses and eight of the participants earned college credit through at least one A.P. exam. Gina took two mathematics courses her second year of high school so that she could get ahead in mathematics. Erin studied FST (Functions, Statistics, and Trigonometry) independently over the summer so she could skip that class and be on track to take Calculus her final year of high school. Bonnie took a mathematics course during her fourth year of high school that covered the content of both Pre-Calculus and

Calculus and spanned two class periods each day. Laurie, Paige, and Nicole all took mathematics courses at nearby colleges while they were still in high school.

This academic motivation did not cease after high school. In college, Kelly and Erin both had the goal of graduating in 3.5 years, and Debra and Carol both planned to graduate in 4.5 years, even though their degree programs were considered 5-year programs at their institution. Also, many of the students took mathematics courses beyond those required for their degree. For example, Laurie was taking graduate level mathematics classes by her third year in college. Paige completed nearly every mathematics course offered at her institution. When asked why she chose to do this, Paige responded, "It was just something that I had to do. I had to. I had to take these courses; they're in my major... so I should."

In addition to the motivation these women demonstrated for taking courses and graduating early, they were also highly motivated when studying for their classes. When Debra took Calculus, she utilized an optional workbook that the instructor recommended for the class. She worked through many of the extra problems in the workbook and then checked the step-by-step solutions shown in the back of the book. Debra felt that doing these extra problems helped her be successful in learning the material in the course.

When taking a course in Abstract Algebra, Gina felt that she was struggling with writing proofs, so she started attending office hours quite frequently:

*"I go [to office hours] so much for homework help, but the majority of it is just to make sure that I understand kinda thing. Make sure that I'm on the right track, you know? That's why like, Dr. B, I'll meet with him. I meet with him fairly regularly, and he'll just go through my proofs and make sure that I'm doing things right. That I'm taking in all considerations and stuff like that. That I'm not leaving pieces out. And if I have a lot of extra stuff, he'll help me cut that out too... I meet with him almost every day that I don't have class with him."*

This strong academic motivation assisted these students in being successful during their academic careers.

### 3.5.2. *Competitive nature*

Many of these students were also academically motivated by competition. Nine of the twelve students either specifically described themselves as competitive or told stories in which they were academically competing with their peers or siblings. For some of them, their competitive nature also extended into non-curricular activities such as sports and trivia games, but each of the nine gave specific examples from academia. Six of these participants told stories from as early as third or fourth grade when they would compete with their peers in learning their multiplication facts or they would learn more advanced mathematics simply to compete with an older sibling. As Gina recalled from fourth grade, “I was really, really into wanting to learn algebra because my older brother was doing it. And so I remember [the teacher] really encouraging me to keep going, and do stuff that we weren’t necessarily covering in class.”

Erin admitted that one main reason she wanted to skip FST and take Calculus in high school was because even though she was already one year ahead in mathematics, she knew some students who were two years ahead in mathematics and wanted to catch up with them:

*“Even though I was on the higher track within classes, I still watched one of my friends and then some other people from my class walk back and forth from the high school, cuz they were taking high school math classes [in 8th grade] and I was like, ‘I wanna take those kind of classes’. So after I passed this FST and then I got into the Pre-Calc, I was with them in class and I was like, ‘**Finally!** I did what I wanted to’.”*

Mandy talked about how her competitive nature in sports really influenced her in the classroom as well:

*“My twin and I played sports so that made us competitive, which may be seen as that guy attribute, being competitive and aggressive... not wanting to give up, persevering, and I think from the field that can also be applied to the classroom. Especially when I’m struggling with math homework, I want to get it. I want to figure it out. I’m gonna keep asking questions and keep trying until I get it.”*

Other participants also spoke of their nature of not quitting and their desire to finish something that they begin.

### 3.5.3. *Going against the grain*

Seven of the participants talked about wanting to go against the grain or do things that people tell them they cannot do. Carol's mother frequently told her that mathematics would be a difficult major and that she should major in an easier subject. Rather than discouraging her, Carol said, "It made me strive even more." Similarly, Joan stated, "A lot of times I think that people don't think I can do something, and that is enough encouragement for me."

This personality attribute also influenced some of these women in their choice of major or specialty. Erin repeated throughout the interviews that part of the reason she wanted to go into mathematics was because she wanted to "break... the gender boundaries." Paige talked about not wanting to do a "traditional mathematical field" but rather, she stated:

*"I think I wanted to do the strange, I call 'the strange mathematical fields.' But a mathematical field that most people don't go into... My mom was kind of like 'Oh, cool. Go. Don't follow the crowd. Go. Go off on your own path'."*

As a result, Paige decided that she wanted to specialize in statistics.

### 3.5.4. *Self-sufficiency*

Seven of these women characterized themselves as being self-sufficient. Some of them even told stories of their parents purposely teaching them how to be self-sufficient. Bonnie explained:

*"And so [my parents] always told me, when I was little, I'd be like, 'I hate you.' And they'd be like, 'You're moving out when you're 18, you know. So you better get prepared. Do you know how to do your laundry yet?' And I'd be like 'No.' And they would show me and then I would learn. So all that kind of stuff... They wanted to make sure that I could take care of myself... I'm pretty independent because of that."*

Carol shared a more recent story. During the semester of the interviews, Carol and her fiancé bought a house together. Being that it was an old house, some repair work needed to be done on it. Carol's fiancé was busy with other responsibilities, so Carol decided to retile the bathroom shower on her own. She shared the story of going to the local home improvement store to buy a book on how to retile a shower. Using the explanation in the book, and her own mathematical know-how, Carol completely retiled her bathroom shower. She prided herself on being able to teach herself and accomplish this large task on her own.

### *3.5.5. Not identifying with gender stereotypes*

Another form of independence that nine of the twelve women demonstrated was not identifying with gender stereotypes. Many spoke about the "boys' toys" they used to play with when they were young, such as Legos and action figures, as well as participating in sports such as football and fishing. Two of the participants even spoke about becoming the sons their fathers never had. Carol recalled:

*"[My father] always wanted boys. He told me when I was, well, after I moved out of the house. He wanted boys, and he's like, 'But, you two girls showed me you can do anything that boys can do, if not more.'... It was really nice to hear that even though he wanted boys, he was really happy with us girls."*

Others talked about their mothers not really fitting the gender stereotypical role. Amy reflected:

*"My mom is not like extremely feminine I guess you could say... I wasn't always in the typical female roles and my mother being my main female role model was not in the typical gender roles... I never really felt hindered just because I was a girl, because I didn't necessarily identify myself as being a girl. I'm just me."*

Many of the participants talked about the importance their future career has to them and that they will not let a relationship jeopardize their future career opportunities. Paige even commented that she intends to have a career that would provide her the opportunity to support herself, her spouse, and any potential children they may have.

Three of the participants (Amy, Bonnie, and Kelly) mentioned that they are not yet decided on whether they plan to have children in the future. Though Carol does intend to have children of her own, she made it clear that she does not believe in following the traditional female role:

*“Just because you’re a girl does not mean that you can grow up and you’re going to cook and you’re gonna be a mommy. You will be those things, but that’s not what your role is. You can do more. Just because there’s a guy there doesn’t mean that you can’t do it, just like a guy can do housework.”*

Though the personality attributes mentioned in this section are not necessarily specific to mathematics, they all are attributes that would assist women in becoming successful in the field of mathematics, which I discuss in more detail in the next section.

#### **4. Discussion**

The purpose of this study was to investigate what motivates women to choose mathematics as an undergraduate major and to further explore what shapes their future career goals, paying particular attention to their undergraduate experiences and their perceptions of the role of gender in these decisions. This study is based on a relatively small sample of only twelve women at two different academic institutions. While their experiences cannot be generalized to represent those of all women mathematics majors, a detailed analysis of their common experiences can provide insight as to why some women are choosing to either persist in or leave the field of mathematics.

##### *4.1. Influences for Persisting at the Undergraduate Level*

This study suggests that two predominant reasons women choose to study mathematics at the undergraduate level are that they have a strong mathematical identity and that they enjoy the subject of mathematics. This was the case regardless of whether they were studying to become a teacher or not. For these women, their strong mathematical identities were initially formed as a combination of high academic achievement in the subject and recognition by others as being a “math person.” The latter played a more predominant role. These women placed an emphasis on the role that family, especially fathers, played in this development. These results are consistent

with the literature. Hall [28] also noted the positive influence that male family figures had in undergraduate women's interest in mathematics. Furthermore, Carlone and Johnson [15] found that recognition by others was a key component to the development of science identities in adult women of color. Carlone and Johnson's work further suggests that the recognition of others is important not only in the initial selection of a career path but also in the persistence in this path after individuals graduate from college.

Enjoyment of mathematics also played a role in these women's persistence in the field. These women simply found mathematics to be fun, frequently making the analogy that mathematics is like a game or a puzzle. They enjoy problem solving and critical thinking and truly appreciate the challenge of the field. Most of all, they desire to learn how mathematics can be applied to other fields and to everyday life activities. Many of these qualities have also been cited by others in the field [4, 28, 60].

As opposed to what is found in the literature, it appears that negative experiences for women in mathematics are not as prevalent as they have been in the past, at least at the pre-college and undergraduate levels [26, 54]. Rather, being a woman appears to increase the amount of encouragement toward entering the field. Though the majority of the women in this study were aware of the societal belief that men are better at mathematics than women, none of them believe this stereotype. Also important is that they perceive this to be a historical belief and argue that society's perspective is changing. They are conscious of the national push to encourage women in the field of mathematics and they, themselves, feel they have received this encouragement and are welcome in the field. These results suggest the numerous intervention programs that have been developed to encourage women to pursue the field of mathematics have succeeded in making many women feel welcome in the discipline.

Although certain talented young women now view mathematics as a field that is welcoming to women, this does not mean all women talented in mathematics necessarily feel comfortable entering the field. Rather, it appears that various personality attributes may assist certain women in making the decision to enter a non-traditional field. In general, the women in my study like accomplishing things they are told that they cannot do. They also enjoy standing out in a crowd. Given that mathematics is often considered a difficult and low-populated field, these personality attributes could possibly motivate both men and women to enter the field. Knowing that historically



women were considered incapable of being successful in the field, however, may specifically motivate talented women with these personality attributes to pursue mathematics. Furthermore, the participants in this study are self-sufficient women who do not identify with gender stereotypes. As such, they are less likely to succumb to pressure to pursue a traditionally female career. It is also interesting that many of the women claimed their parents influenced these attributes within them, suggesting that they believe these attributes are not innate but were gained through environmental influence.

Although women with the characteristics above may be more likely to pursue careers in non-traditional fields, other characteristics may explain why mathematics is more appealing to those who choose to pursue mathematical careers. The women in this study are academically motivated and enjoy a challenge, often citing this latter characteristic as a reason for enjoying mathematics. Other scholars have also noted the challenge of mathematics as an appealing attribute to those in the field [1, 14, 28, 40]. The literature also suggests that the competitive way in which mathematics is frequently taught often makes it unappealing to women [66]. While most of my participants frequently collaborated with their peers, they also described themselves as competitive. Given that a substantial number of school-age girls now participate in team sports, the competitive nature of the mathematics classroom may become less of a concern for many women in future years.

#### *4.2. Mathematics and Women's Future Career Goals*

The mathematician does not study pure mathematics because it is useful; he studies it because he delights in it and he delights in it because it is beautiful.

—JULES HENRI POINCARÉ.

As eloquently stated by Poincaré, many mathematicians enjoy mathematics for its beauty, and not necessarily for its applicability. A sheer appreciation of mathematics was also displayed by the women in this study, many of them citing their enjoyment of the field as a predominant reason for choosing to study it at the undergraduate level. In addition to its beauty, many of the women appreciate the game or puzzle nature of mathematics. This, too, has been cited as motivation to study mathematics by others [4, 60]. While this is one characteristic individuals tend to enjoy about the subject, it may also be one of the fatal reasons why many women do not choose to pursue a career in mathematics. When considering the qualities they desire in a future

career, the women in my study most frequently cited wanting a career where they can help people. Although they view mathematics as enjoyable, they cannot justify “playing games” for a living. As they started thinking about their future careers, they became determined to do something meaningful with their lives and the abstract, game-like nature of mathematics did not seem to fulfill this need.

In addition to wanting “helping” careers, the next most commonly desired quality in a career was one that involved social interaction. Morgan, Isaac, and Sansone [44] grouped these two career qualities (working with people and helping others) under the same category of “people-oriented” careers. In their work, they found that amongst college students of various majors, while both men and women desired “people-oriented” careers, women cited this as a reason for their intended career plans at a significantly higher rate than men. Furthermore, these scholars also found that college students, both men and women equally, perceived careers in the physical and mathematical sciences less likely than other careers to meet their interpersonal goals. Thus their work suggests that while these perceptions of mathematics may be deterring both men and women from entering the field, it may be affecting women at a higher rate.

Also noteworthy was the students’ interest in real-world mathematical applications and connections. The majority of the participants spoke of appreciating mathematical connections to everyday life activities, such as landscaping around a pool and skiing, and some also discussed wanting careers where they can apply mathematics to other fields, such as biology. Though they *enjoy* the game/puzzle aspect of mathematics, it appears that their desire for real-world applications were, in part, in order to justify their field to others and to assist in discerning a career in the field.

The women in this study wanted to see the big picture of the field and how it relates to the real world, yet instead they felt that in their college mathematics courses they were simply “doing math to do the math.” Lambertus, Bracken, and Berenson also found that the young women in their study “felt mathematics should connect to real life and not simply be learned in isolation” [40, page 357]. Such connections and applications may also assist these women from feeling isolated from the people in their lives who do not study mathematics. For example, abstract algebra was specifically cited by my participants as being a course taught completely void of any real life applications. However, group theory has applications in many fields, such

as chemistry [9], physics [61, 65], and even in solving the Rubik's Cube [36]. Learning the very basics of these real-world applications, or even that they exist, both could assist students in seeing the big picture of the content they are learning and could help them justify their coursework to others.

Other scholars have also noted young women's preference for mathematical applications [1, 28]. Though no national trend can be seen in the degrees earned at the undergraduate level, a trend does appear in graduate programs in the U.S., especially in the area of statistics [45]. In 2009, women earned 41% of the master's degrees and 33% of doctoral degrees in the mathematical sciences, but earned 47% of the master's degrees and 46% of the Ph.D.'s awarded specifically in statistics [17, 18]. Furthermore, of all doctoral degrees awarded to women in the mathematical sciences in 2009 and of the twelve different mathematical fields listed by the American Mathematical Society<sup>6</sup>, 52% of women wrote dissertations in either statistics/biostatistics or applied mathematics [17]. These numbers suggest an interest by women in mathematical applications. This is contrary to the fact that women still earn comparatively few degrees in computer science, physics, and engineering [48], all of which are fields that apply mathematics. More research should be conducted to explore why women may find some fields that apply mathematics more appealing than others.

It is also important to note the lack of knowledge the participants in my study had of possible careers available to them in mathematics. Moreover, all of the women in this study who were not intending to become teachers cited this as a main obstacle for someone wanting a career in mathematics. Other scholars have also documented the lack of career knowledge by mathematics students [1, 51, 60]. It is possible that this is a predominant reason that the field loses both men and women. As a result of not knowing what careers are available in mathematics, they choose to pursue careers that they are knowledgeable about. I would further conjecture that this phenomenon affects women more frequently than men. When unaware of possible career

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<sup>6</sup>These twelve mathematical fields are: 1) Algebra/Number Theory, 2) Real, Complex, Functional, and Harmonic Analysis, 3) Geometry/Topology, 4) Discrete Mathematics/Combinatorics/Logic/Computer Science, 5) Probability, 6) Statistics/Biostatistics, 7) Applied Mathematics, 8) Numerical Analysis/Approximations, 9) Linear Nonlinear Optimization/Control, 10) Differential, Integral, and Difference Equations, 11) Mathematics Education, and 12) Other/Unknown [17].

options in their field, women may be more likely to turn to gender-traditional careers, especially those women who have a preference for “people oriented” careers.

#### *4.3. Possible Implications*

The results of this study allude to a number of possible implications. It appears that individual encouragement and recognition by others continue to be instrumental in some women’s interest and persistence in mathematics. Therefore, it is important for parents, teachers, professors, and advisors to continue to encourage and support women in their interest in mathematics. Ideally, this encouragement would begin at a young age, but ought to be continued throughout their educational careers. Furthermore, my results suggest that the national agenda to encourage women in the mathematical sciences appears to be successful in presenting the message to many talented young women that they are welcome and wanted within the field. Therefore, in addition to individual encouragement, the development and existence of programs designed to encourage and support women to pursue mathematics likely will continue to change the climate of the field.

While the support and encouragement of others may be instrumental in the participation of women in mathematics, it certainly is not sufficient. I propose that the attrition of women from mathematics following the undergraduate degree is directly impacted by the fact that this is the stage when many people determine their future careers. Enjoyment, achievement, and the support of others may motivate many women to major in mathematics, but these do not appear to be sufficient for pursuing a career in the field. Regardless of their interest in mathematics, if women are not aware of careers in the field that they find both fulfilling and satisfy their desire to work with people, they likely will not choose to continue in the field. Therefore, both high school and college students need more access to information on mathematical careers, especially careers that are considered “people oriented” careers.

Although there is substantial career information on the Internet, none of my participants mentioned doing Internet searches to learn about potential careers. It is possible that they had conducted such searches, but if so, they did not mention this as a means of gaining new career information. Is it possible they were unable to determine which sources were reliable? Or were they unable to sort through the abundance of information available online? Or

did they have trouble finding “people oriented” careers? Or did they simply not utilize the Internet when considering future careers? Regardless which of these situations it is, I would argue that mathematics students would greatly benefit from their faculty knowing more about mathematical careers, openly sharing this information with their students, and being able to direct students to reputable sources for information. For example both the Mathematical Association of America (at <http://www.maa.org/careers>) and the American Mathematical Society (at <http://www.ams.org/careers/>) have created websites with information about mathematical careers. Also, many books have been written to provide students with information about mathematics-based careers (for example see [13, 39, 62]). However, simply directing students to these websites and books may not be enough; helping them parse the wealth of information available through these resources may also be a necessary step.

Finally, women’s interest in certain areas of mathematics and statistics known to have applications ought to be acknowledged and seized. In more recent years, statistics courses have become more prevalent in U.S. high schools. Potentially, this could encourage more students to pursue statistics at the collegiate level. In addition, further coursework and programs that emphasize areas of mathematics known to have applications may also interest more women to pursue, and persist with, mathematics. Therefore, mathematics departments, where feasible, should consider creating majors and/or programs in statistics and applied mathematics, if they do not exist already.

Furthermore, faculty who teach courses that are predominately theoretical in nature could utilize in their classes, or direct their students to, resources describing applications of the content. One resource is the *Math Matters, Apply It!* campaign of the Society of Industrial and Applied Mathematics (<http://www.siam.org/careers/matters.php>) which has been created to inform individuals about the mathematics behind many everyday life topics and situations, such as reconstructive surgery and renewable wind energy. This initiative currently has 31 PDF files available. Each file is based on a different topic and explains the technical terms used, uses and applications, how the mathematics works, and interesting facts with regards to that topic. In addition to potentially enticing more women to continue with mathematics, such additions to traditionally theoretical coursework could better prepare students for many mathematical careers available in industry by helping

them “understand the role of the mathematical sciences in the wider world of science, engineering, medicine, defense, and business” [46, page 3].

Coupled with helping students see mathematical connections between their coursework and other fields, introducing these applications can assist students in developing a more humanistic perspective of mathematics. Rather than viewing their theoretical classes as being solely an exercise in mathematical fun, students will be able to construct a bigger picture of how the field is situated in and relevant to the world around them. Information about the historical development of topics will further assist students in viewing mathematics as a human endeavor.

Certainly, more advising of all high school and college students of careers available in mathematics is needed. Specifically, information about “people oriented” careers in mathematics may be particularly appealing to many students. Furthermore, increased advising of women to enroll in applied mathematics and statistics courses or programs may assist many women in learning how to combine their passion for mathematics with their desire to apply the mathematics that they learn. While this may not increase the number of women in pure mathematics, it may help prevent the loss of talented women from the mathematical sciences altogether.

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