WOMEN'S HIGH SCHOOL AND UNIVERSITY EXPERIENCES THAT INFLUENCE THE PURSUIT OF UNDERGRADUATE MATHEMATICS DEGREES

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This paper situates and describes my current research on gender issues in mathematics at the post-secondary level in Canada. I first present the current situation, a chronology of perspectives on the issue, and other related empirical studies. I then present the findings from my pilot study and the status of my current research, both of which describe and explore the experiences of women who persevered with mathematics at the undergraduate degree level.

INTRODUCTION

Gender issues in mathematics are an important topic of research in Canada. Mathematics participation and achievement have reached equality between the sexes at the elementary and secondary level (Hanna, 2003), but this is not the situation at the post-secondary level, where women are clearly the minority of participants (Gallada, 2001). Furthermore, although parity has been reached in terms of participation in other previously male-dominated fields of university study such as business and medicine (Freeman, 2004), the proportion of women enrolling in and graduating from Canadian undergraduate mathematics degree programs has actually decreased in the past decade (Statistics Canada, 2008a; Statistics Canada, 2008b). To address this situation, we need to better understand what factors contribute to the marked gender differences in participation in mathematics at the post-secondary level.

The current Canadian situation points to issues of equity, particularly gender inequities in terms of educational outcomes. Although there are several ways in which equity can be considered, I turn to Fennema (1990), who discusses three aspects of equity in mathematics: equal opportunity to learn mathematics, equal educational treatment, and equal educational outcomes. Most relevant to this situation is the third aspect, equal educational outcomes; if this type of equity existed, Fennema (1990) notes that "At the end of public education, there would be no gender differences in achievement or in how males and females felt about themselves and mathematics" (p. 4). This relates to the second aspect of equity, as inequitable treatment by teachers can lead to inequitable educational outcomes, which thus can have significant impacts on students' selections of mathematics as a field of post-secondary study. Given the current

inequitable situation in this field, it is vital to investigate why the relatively few women who selected and persisted in an undergraduate mathematics degree program did so.

Thus, my research focuses on the mathematics experiences of women who are currently enrolled in upper years of an undergraduate mathematics degree program – women who not only enrolled but persisted with their degrees beyond the initial years of study. In this paper, I share the results of my pilot study and outline my full study. While data collection is currently occurring, I expect to be able to share preliminary results of my full study, as well as my pilot study, at the ICME-11 conference.

Situating the Problem

In the past few decades, great strides have been made in terms of equitable achievement and participation of males and females in the field of mathematics at both the elementary and secondary level in a wide variety of countries (See FIMS, SIMS, and TIMSS outcomes outlined in Hanna, 2003). At the post-secondary level, several previously male-dominated fields, such as medicine, law, and business, have now reached equity in participation. Indeed, as of the 21st century, women earned more than half the undergraduate university degrees in many Western nations (Freeman, 2004), but their participation is still limited in fields that are considered to be more 'masculine', such as mathematics, engineering, and physics – the 'hard' sciences.

The situation of enrolment patterns of women and men in post-secondary education in Canada is much the same. Although enrolment of women in stereotypically 'masculine' fields of study has shown an increase in the past few decades, this increase is very minimal and still places women in the minority (Gallada, 2001). The ratio of females to males enrolling in undergraduate degree programs in mathematics and related subject areas (information and computer science) has actually decreased from approximately 0.43:1 in the 1992/1993 school year to approximately 0.33:1 in the 2004/2005 school year (Statistics Canada, 2008a). Similarly, Figure 1 shows how the increase in the number of female graduates from mathematics and related fields at the undergraduate level is far less than that of male graduates; in fact, the ratio of female to male graduation rates in these fields has also decreased, from approximately 0.5:1 in 1992 to 0.37:1 in 2004 (Statistics Canada, 2008b).

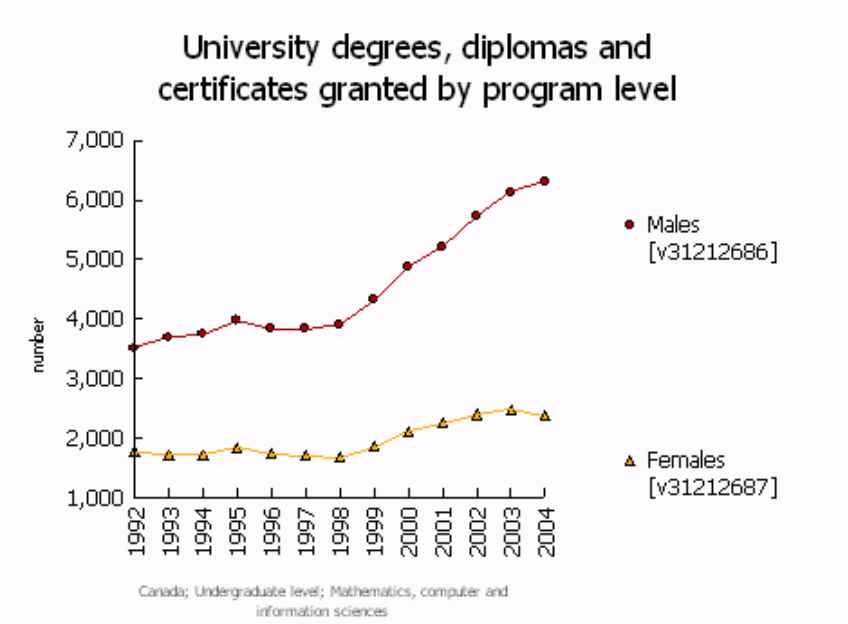

Figure 1. Number of graduates from Canadian undergraduate programs in mathematics and related fields (computer and information science).

Although quantitative data regarding enrolment and graduation rates in mathematics degree programs in Canada are available, the existing body of Canadian literature is lacking in regards to the factors that support enrolment and perseverance in this field. The aforementioned Gallada paper (2001) provided a comprehensive overview of the statistics regarding women in male-dominated fields of university study in Canada, but did not provide detail about factors that support women's enrolment and perseverance.

Addressing the Problem

My research examines a specific population that has had very little previous attention in the research literature – females in upper years of undergraduate mathematics degree programs who have been educated in Canada for all levels of education. The study is guided by the following research question:

In what ways do Canadian women who are nearing completion of undergraduate mathematics degrees feel they have been supported and challenged in their high school and university mathematics studies?

This question is investigated with an exploratory framework of semi-structured interviews regarding the participants' personal characteristics and experiences with the formal

education system, family members, and peers. By highlighting trends in the participants' interview responses, this research identifies contributing factors to these women's selection of and perseverance with undergraduate mathematics degrees.

Achieving equality in mathematics participation at the university level is an important goal, and this study will add to the understanding of the complex interplay of educational, social, and personal issues that affect women's decisions to select and pursue undergraduate mathematics degree programs. Although studies of a similar nature have been conducted, very few were in Canada, and of those, virtually none used qualitative methods that provide insight into the stories behind the enrolment and graduation statistics. If equality at the undergraduate level is achieved, there will subsequently be more females available for higher degrees and academic positions in mathematics. Having more females in post-secondary mathematics may lead to expanded research directions and provide more female role models.

EVOLUTION OF PERSPECTIVES ON GENDER AND MATHEMATICS

A variety of theories have evolved over time to explain gender differences in mathematics. I focus on two general themes that have been used to explain gender differences in participation and achievement: one explanation relates to biological differences, whereas the other relates to social and cultural factors. While these theories are generally presented in a chronological order to provide a historical perspective, it is also important to understand that many theories overlap chronologically, and some of the earlier theories and ideas are still held today by some individuals (e.g., Halpern, 1997; Summers, 2005).

Biological Differences

Throughout much of Western history, mathematics was considered to be inherently foreign to the female mind, and issues surrounding women in mathematics and science were not a prevalent theme in research literature until the 1960s (Hanna, 2003; Leder, 1992; Simon, 2000). However, in the 1960s, equality of access to education in mathematics and science for women became one of the predominant aims of the feminist movement and researchers thus turned their focus to this issue (Hanna, 2003). Reports on the history of gender issues in mathematics (Hanna, 2003; Leder, 1992) note that much of the early research in this field attributed the inferior performance and under-representation of women in mathematics and

science to innate biological factors. Several early studies (e.g., Benbow, 1988; Benbow & Stanley, 1980; Fruchter, 1954; Stafford, 1972) focused on biological explanations for differences between males and females in spatial perception and mathematical reasoning ability. However, other researchers questioned the biological focus and examined other issues that might affect females' experiences with mathematics. For instance, Fennema and Sherman (1977) pointed out that when the number of prior mathematics courses taken and experience with spatial activities were controlled, no sex differences in spatial abilities were found.

Exploring Other Possibilities

Fennema and Sherman's study (1977) with American high school students went beyond an examination of spatial skills to explore beliefs about mathematics and found that many of these beliefs affected female participation and achievement. They found that females generally held the belief that mathematics is a male domain. The more the female students believed this stereotype, the lower their achievement in mathematics. Females were also found to have lower mathematics confidence and to find mathematics less useful than males. However, Fennema and Sherman recognized that these beliefs were socially constructed and that social and cultural factors can relate to mathematics achievement. This was the beginning of a shift in the focus of research with respect to gender and mathematics education.

Society and Culture

As research shifted from a focus on biological differences in mathematics ability to a focus on society and culture, there was also a change in terminology from 'sex differences' to 'gender differences'. This seemingly small change in wording represented a significant change as 'sex' is a biological term whereas 'gender' refers to socially constructed roles or identities (Pryzgoda & Chrisler, 2000). Hence, differences are not seen as innate, but rather are linked to societal perceptions and thus are not immutable. Hanna (2003) provides the following useful summary:

> Most modern educational research on gender similarities and differences suggests no physical or intellectual barrier to the participation of women in mathematics… it is now generally accepted that women have been and continue to be underrepresented in these fields mainly because of social and cultural barriers that did not and still may not accord them equal opportunities. (p. 205)

The shift in research focused on examining how mathematics is viewed in Western culture, how women's relationship with mathematics is viewed, and the implications of these views on gender equity issues in mathematics education. As such, research included examining social and cultural factors such as stereotypical identifications, media portrayals of women and mathematics, and parental and teacher expectations, views, and treatment of females in mathematics.

In general, mathematics tends to be viewed as a "logical, clinical, creative, objective, and complex pursuit" (Forgasz & Leder, 1996, p. 129). Since historically, women have been perceived to be "less competent, less independent, less objective, and less logical than men" (Broverman, Vogel, Broverman, Clarkson, & Rosenkrantz, 1972, p. 75), they have not been seen to align with the study of mathematics. Even in more recent years, mathematics has still been stereotyped as a male domain (Boswell, 1985; Fox, Brody, & Tobin, 1985; Mendick, 2005). Furthermore, women are bombarded by the media, parents, teachers, and other individuals with the message that mathematics is difficult for women, women perform inferiorly, and mathematics achievement is simply less important for women (Damarin, 1993).

Societal views have been clearly shown to influence students' beliefs about gender roles and mathematics, both at the elementary and high school level. Forgasz and Leder's study (1996) of Australian Grade 9 students found that males considered mathematics to be 'masculine' whereas both sexes considered English to be 'feminine'. Similarly, males considered males to be better at mathematics whereas both sexes considered females to be better at English. A more recent study by Lupart, Cannon, and Telfer (2004) of Canadian Grade 7 and 10 students found that, even though girls have a better attitude toward learning for learning's sake, boys have much better attitudes toward and interest in mathematics. Clearly, society's views of women in mathematics affect students' perspectives on gender roles in mathematics, which can have far-reaching implications for students' educational choices.

Current Views

Recent research has focused on the notions that mathematics itself, both as a discipline and the way it is taught, may be to blame for gender differences, rather than the attributions and motivations of girls themselves. The notion that teaching should be connected to different ways of learning and that those ways of learning may be connected to gender has been attributed to a number of researchers (Becker, 1996; Belenky, Clinchy, Goldberger, & Tarule, 1986; Gilligan,

1982). These gendered differences in ways of learning are attributed to differences in socialization rather than innate biological characteristics.

Hence, research has focused on how females learn mathematics and a variety of different scenarios of classroom experiences have been investigated, including single gender classes, mentoring, particular pedagogical practices in co-educational classrooms, and intervention programs such as summer math camps (e.g., Becker, 2001; Boaler, 1997; Campbell, 1995; Freeman, 2004; Goodell & Parker, 2001; Kerr & Kurpuis, 2004). Boaler (1997) describes how girls' underachievement and lack of participation can be attributed to the structured, traditionalist manner in which mathematics is often taught. Several researchers have found that in a traditionalist classroom, girls tend to exhibit rule-following behaviours (Karp & Shakeshaft, 1997; Scott-Hodgetts, 1986) and excel at rote learning (Ridley & Novack, 1983; Schmittau, 1996). However, merely memorizing procedures is not adequate preparation for higher-level mathematics that may require students to engage in solving problems in unfamiliar contexts. Further, the competitive setting of the traditional classroom does not provide a safe space in which to take the necessary risks to engage in meaningful problem solving (Boaler, 1997).

Boaler (1997) found that in an open, connected environment that uses co-operative learning, females are more comfortable to engage in meaningful mathematics exploration. Her three-year longitudinal study of a traditionalist school and a project-based school found much greater strides in females' attitudes, conceptual understanding, and achievement in the latter. Boaler concluded that only by changing the system can the greatest improvements in gender equity be realized. This parallels the thinking of those with a feminist perspective who have advocated for more variety in assessments, cooperative grouping, problem solving, and inquiry methods that employ real world contexts as a way to connect more women to mathematics (Morrow & Morrow, 1995).

However, some contend that the issue of women in mathematics has been solved and gender equity has been achieved. For instance, while a full chapter in the *Handbook of research on mathematics teaching and learning* (Grouws, 1992) discussed gender issues, the topic does not even explicitly appear in the table of contents in more recent handbooks (English, 2002; Lester, 2007). In fact, some research has turned to focus on boys in mathematics as there are some recent trends that suggest there is a low enrolment of boys in secondary mathematics classes, and there is a perceived bias as more boys are placed in special education classes in

mathematics (Kleinfeld, 1998). This shift may detract from continuing efforts to promote females' increased participation and achievement in mathematics.

While the past twenty-five years have brought considerable progress for females in mathematics at the elementary and secondary levels (Campbell, 1995; Hanna, 2003; Kleinfeld, 1998), the data I have presented suggest that there is still significant work to be done at the university level.

REVIEW OF SIMILAR STUDIES

Choosing to Study Mathematics

Many research studies have been conducted, both in Canada and internationally, that examined factors that affect women's choice of mathematics as an undergraduate field of study. In particular, females' mathematics experiences at a high school level are frequently a factor in determining whether women choose to enrol in mathematics at a university level. Thus, studies about this topic tend to examine female's experiences and attitudes with mathematics.

Several studies suggest that female high school students do not have positive perceptions of mathematics and therefore elect not to study it, which may explain the low enrolments in mathematics at the university level. Researchers investigating females' attitudes toward mathematics and science in high school found that males tend to have more positive attitudes toward these subject areas (Lupart, Cannon, & Telfer, 2004; Forgasz & Leder, 1996; Weinburgh, 1995). The less positive attitudes of females toward mathematics and science were also shown to correlate with lower achievement in these subject areas (Fennema & Sherman, 1977; Weinburgh, 1995), which decreases their chances of acceptance to university mathematics programs. Even when outperforming males in mandatory high school mathematics courses, females still tend to drop mathematics as soon as they have the option (Freeman, 2004; Karp & Shakeshaft, 1997; Stewart, 1998). Similar findings about high school students' attitudes toward math appear in the questionnaires that accompany large-scale assessments of mathematics achievement. For example, McGraw, Lubienski, and Strutchens (2006) conducted an analysis of questionnaire data from the U.S. National Assessment of Educational Process (NAEP) survey of Grade 4, 8, and 12 students from 1990 to 2003. They found that female students were less likely than male students to indicate that they liked math or to consider themselves to be proficient in the subject, although males and females reported equal levels of understanding in class.

While the above studies point to factors that inhibit females from choosing mathematics, studies of those females who did select mathematics-related university programs provide insight into the factors that prompt such a choice. Gill's study (2000) of Canadian first- and second-year female students in mathematics-related fields examined three dimensions (intrapersonal, interpersonal, and contextual) via in-depth interviews and found that the women were most heavily influenced by intrapersonal factors, such as passion about and skill in the subject area. Interpersonal factors, such as supportive relationships with teachers and parents, were also significant to these women's selection of university fields of study. In terms of contextual factors, special educational or after-school programs and opportunities for group work were shown to be positively linked to the choice of a mathematics-related degree program.

Persevering in Mathematics

Other studies have examined females' perseverance or attrition in mathematics degree programs, and have identified a wide variety of factors that promote or inhibit perseverance in a mathematics program. I will first address those factors that promote females' perseverance in mathematics-related fields. One factor that has been shown to lead to perseverance is supportive relationships with faculty and positive teaching practices (Gavin, 1996; Seymour, 1995). Studies also found that personal qualities such as competitive attitudes, determination, coping strategies, superior abilities, pride and belief in abilities, and serious academic attitudes tend to lead to continuing in mathematics-related programs (Gavin, 1996; Rodd & Bartholomew, 2006; Seymour, 1995; Zhao, Carini, & Kuh, 2005). Some research also shows that having highly educated parents and strong parental support are positive influences for perseverance (Gavin, 1996; Blair, 1991).

With regards to attrition, numerous reasons have been identified, such as poor interactions with faculty, feelings of being invisible or not fitting in, a low percentage of females in the program, and a loss of interest in the subject area. Several studies pointed to faculty interactions and poor pedagogical practices as problematic (Herzig, 2004; Sax, 1994; Seymour, 1995). Studies also point to women's feelings of not fitting in (Damarin, 2000; Herzig, 2004; Rodd & Bartholomew, 2006). Herzig (2004) noted that the women in her study felt that they did not belong at the mathematics department, which one participant described as "the old white guys' club" (p. 385), which is similar to feelings of being invisible reported by participants in Rodd and Bartholomew's study (2006). Other factors related to attrition have been recognized,

such as loss of interest in the subject, an interest in another subject, and a feeling of being overwhelmed with the pace and demands of the curriculum (Seymour, 1995).

MY RESEARCH

The aforementioned studies have shown that there are a wide variety of factors that influence female students' choice to enrol and persevere in mathematics-related fields of study at the university level. Sociological factors, such as personal characteristics and the impact of peers, family, and educators, have been noted to play a key role in women's enrolment and perseverance in mathematics. Although these studies are useful in informing my research, they do not encompass the unique combination of issues I feel are essential to addressing the problem.

Pilot Study

Prior to my current research, I conducted a pilot study that consisted of semi-structured one-on-one face-to-face interviews with three women who had completed non-traditional degrees, such as Engineering, Physics, and Mathematics, and who were currently enrolled in a Bachelor of Education program. I used a semi-structured interview protocol consisting of 10 open-ended questions in order to attempt to learn what factors had contributed to their perseverance with their degrees. The semi-structured nature of my interview protocol allowed for exploration of issues in an in-depth manner as participants' answers could be followed up (Creswell, 2005). The interviews allowed each participant to share her story and how she interpreted it; this allowed me to understand "the lived experience of other people and the meaning that they make of that experience" (Seidman, 2006, p. 9). I analyzed the interview data using methods informed by grounded theory.

Three common themes appeared to support the women in their educational experiences in non-traditional fields. First, all participants had personality traits that I believe helped them persevere. They all tended not to care what others thought, were not overly sensitive, and were self-directed learners. Also, the women tended to be very social with excellent verbal skills, which helped them to obtain strong peer networks. Second, all women had a great love of and skill for their subject areas. All women noted that their love of the subject area was long-standing, and they all were visibly passionate during the interviews. Furthermore, all participants were particularly talented in their subject areas, as is shown by their participation in gifted

programs, early entry into university, and standings on the Dean's List. The third theme that arose was that the women were supported informally in their academic endeavours by their peers. Some women found their peers to be helpful when they were struggling with academic content whereas others found their peers to act as more of a psychological support network. It is important to note that none of the participants mentioned being assisted by formal support networks such as professors, teaching assistants, or help centers (Hall, 2006).

This pilot study has guided my current research in many ways. First, I used my pilot study's interview protocol as a template for my current research, though I added some questions and altered the dimensions to better align with the existing literature. Secondly, I have decided to strictly use participants in mathematics degree programs in order to ensure a greater homogeneity among participants so I can delve into issues specific to that subject area. Finally, after encountering a participant in my pilot study who completed all her schooling prior to her Education degree in another country where these gender issues in mathematics do not exist, I decided to strictly use participants in my current study who were educated at all levels in Canada, in order to control for cultural variables and better understand Canadian issues.

Instrument Design

The interview protocol for my full study arose from that used for my pilot study, but with a slightly different organization and with more grounding in the existing literature. The eight open-ended questions in the interview protocol cover the participant's mathematics experiences in high school and university with regard to the influence of the following four dimensions: the formal education system, family, peers, and personal characteristics. These dimensions were selected as they have been shown in similar studies to have a significant impact on women's experiences in mathematics.

Specifically, the first two questions inquire about the participant's current university program and her choice of this program, in order to ease into the interview with simple, ice-breaker-type questions. It is important to use such a method in order to build rapport with participants, which is fundamental to the tone and outcome of the interview (Creswell, 1998; Seidman, 2006). Each of the remaining questions (#3 to 8) includes several follow-up questions that I could potentially ask to obtain further information. Questions #3 and 4 ask about the participant's high school and university educational experiences (Formal education system dimension). Previous research literature has shown that specialized educational experiences and

relationships with teachers have significant impacts on women's decisions to enrol and persist in mathematics (Becker, 1996; Gavin, 1996; Gill, 2000; Herzig, 2004; Rodd & Bartholomew, 2006). Question #5 inquires about the role of the participant's family, both parents and siblings (Family dimension). The impact of family members, particularly parents, has also been shown consistently to be significant in women's choice of and perseverance in mathematics (Gavin, 1996; Gill, 2000; Rodd & Bartholomew, 2006). Questions #6 and 7 ask about the impact of peers in high school and university (Peer dimension). This topic is most frequently seen in the literature in terms of gender-role attitudes at the high school level (Fennema & Sherman, 1977; Forgasz & Leder, 1996; Lupart, Cannon, & Telfer, 2004), but some direct impacts have also been noted (Gill, 2000; Hall, 2006). Finally, Question #8 inquires about personal characteristics of the participant that may have impacted her mathematics experiences (Personal characteristics dimension). Several studies have examined the characteristics of females in the field of mathematics and tend to show similar results, such as the women being competitive, having serious academic attitudes, being separate knowers, having great passion for their subject area, and being proud of their superior mathematics abilities (Becker, 1996; Gavin, 1996; Gill, 2000; Hall, 2006; Rodd & Bartholomew, 2006; Zhao, Carini, & Kuh, 2005).

Considerations in Design

Recall of past events may be problematic in almost all means of data collection, but particularly so in one-on-one interviews as participants may feel on the spot and may respond quickly without thinking about their answers. To combat this problem, participants should be asked to reconstruct past experiences, as opposed to simply remembering, since reconstruction "is based partially on memory and partially on what the participant now senses is important about the past event" (Seidman, 2006, p. 88). The design of my interview protocol is such that it slowly eases the participants into recall with simple demographic questions and then progresses to more complicated questions. Furthermore, each main question (#1-8 in the interview protocol) is linked to several follow-up questions, which may stimulate recall in the participants better than the more open-ended main questions.

Participants

I am currently collecting data and am in the midst of conducting interviews. The research design calls for approximately eight participants drawn from women enrolled in the

undergraduate degree program in Mathematics at the University of Ottawa, and I have completed two interviews thus far. The women that I am recruiting are currently in either third or fourth year of their undergraduate studies and must have completed all levels of their previous education (elementary and secondary) in Canada, to control for cultural variables.

Given my similar educational background, I believe I am at an advantage in developing bonds with my participants and gaining an insider's perspective. I believe participants open up to me more so than with an 'outsider', be it a man or non-mathematician. However, my similarities to my participants could be construed as a limitation as I may affect the participants' responses. By sharing my background but not my opinions on women in mathematics, I will elicit more honest and unbiased responses and gain insight into my participants' lives.

Data Collection

Data collection occurs through a single semi-structured interview of approximately one hour in duration per participant. Each interview is conducted by the researcher, using the interview protocol, and audio-taped in order to allow for transcription. Interviews are being conducted in Winter of 2008 on the University of Ottawa campus. During the interviews, I try to maintain a conversational tone and rapport with the participants, so I do not take notes, as I feel it is distracting and makes the participants feel as though they are being 'studied'. However, if I notice anything significant during the interview, such as noteworthy facial expressions or gestures (e.g., eyes filling with tears), I make notes immediately after the participant leaves.

Data Analysis Methods

I transcribe all the audio-taped interviews verbatim. Then, I analyze the data using methods informed by grounded theory techniques. I initially analyze the transcripts by searching for main themes to emerge regarding factors that either supported or challenged these women in their mathematics experiences. Then, I summarize key themes in a table, both within each participant's data and between participants' data. Finally, I create a concept map that highlights how the themes contributed to these women's experiences in mathematics, particularly during their undergraduate degrees.

Current Status of Research

To reiterate, the pilot study's three key findings were as follows: participants had personality traits that helped them persevere; they had a great love of and skill for their subject areas; and they were supported informally in their academic endeavours by their peers (Hall, 2006). The current study is in data collection phase, with some initial analysis occurring. Data collection should conclude by the end of March, and analysis should be complete by the end of May. The findings from this study will be compared to those of the pilot study, and will be presented at the ICME-11 conference in July.

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