5-13-2011

It's Nothing Personal: Competing Discourses for Girls and Women in Mathematics

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“IT’S NOTHING PERSONAL”:
COMPETING DISCOURSES FOR GIRLS AND WOMEN IN MATHEMATICS

A Dissertation Presented

by

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Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF EDUCATION

May 2011

Teacher Education and School Improvement

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DEDICATION

To my beautiful wife Cathy.

ACKNOWLEDGMENTS

I would like to thank all of the people who have supported me throughout the writing of this dissertation. First, I would like to thank my advisor, Dr. Sally Galman for all of her guidance over these past four years. I would also like to thank Dr. Barbara Madeloni, Dr. Kathy Davis, and Dr. Donna Riley for providing their valuable contributions as members of my dissertation committee. Similarly, I'd like to thank Dr. Ruth-Ellen Verock-O'Loughlin, Dr. Sandy Madden, and Dr. Cynthia Rosenberger for their friendship, mentoring, and ongoing encouragement.

I would also like to thank all of my friends and family who have unconditionally supported me through this challenging endeavor. I am especially grateful to my wife Cathy, who not only transcribed interviews and edited my drafts, but was also there to pick me up in my moments of self-doubt or frustration.

My sincerest gratitude also goes out to Drs. Charlene and Jim Morrow for granting me access and welcoming me so warmly into the SummerMath community. And finally, I'd like to thank all of my participants for generously donating their time for this study. I could not have done this research without them.

ABSTRACT

"IT'S NOTHING PERSONAL": COMPETING DISCOURSES FOR GIRLS AND WOMEN IN MATHEMATICS

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This dissertation used a post-structural feminist theoretical lens to examine women's under-representation in mathematics graduate programs and careers. Five dominant discourses that potentially influence women's decision to enter mathematical careers were discussed, including how those discourses interact in competing and complementary ways to shape women's and men's ideas about the nature of mathematics. The study investigated the long-term impact of a single-sex reform-based summer mathematics program on high school girls. The study utilized a variety of data collection techniques including surveys, field observations, phenomenological interviews, and artifact collection. Nine participants who were enrolled in a summer mathematics program for high school girls in 2000 were purposefully selected to best represent the overall population of program participants during that time period.

Results of this study indicate that these women rejected the traditional procedural way that mathematics was taught to them. They saw mathematics as irrelevant and had very little knowledge of potential careers in mathematics. However, the findings of this study suggest that programs like the one studied here can have positive outcomes on girls' academic performance, their perceptions of their own math ability, and their perceptions of mathematics as field of study. Overall, this study allows researchers to better understand the lived experiences of women in mathematics, hopefully leading to a more dynamic model that can begin to explain how competing discourses influence girls' and women's decision to enter mathematics careers. Based on these findings, recommendations for changes in teaching practice are discussed.

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CHAPTER 1

THEORETICAL FRAMEWORK

> Feminist research about girls and women would seek to help them understand and transform their place in mathematics education rather than working to identify differences between female and male students (Fennema & Hart, 1994, 655).

Introduction

In this chapter, I will outline one interpretation of the problem of women's under-representation in mathematical careers. Using a post-structural feminist theoretical lens, and specifically the deconstruction methodology of Foucault (1990, 1995), I will examine the various discourses that influence women's decision to enter mathematical careers. In particular, I will describe the five dominant discourses that I believe influence women's decision to enter mathematical careers, how those discourses are both competing and complementary, and how they shape both women's and men's ideas about the nature of mathematics, and who is capable of doing mathematics. I will also discuss how the emergence of counter discourses through consciousness raising might interrupt the dominant discourses and result in long-term changes in the girls themselves, as well as the field of mathematics.

Problem Statement

Mathematics is commonly identified as the primary gateway to high paying employment, financial independence, and high status occupations (Besecke & Reilly, 2006; Burton, 1995). It has been deemed the "critical filter for employment and full participation in our society" (Stanic, 1989, 58). Thus, gender, racial, and socioeconomic inequities in mathematics participation could be a source of cultural and social inequity in our society.

The gender gap in mathematics achievement has been remedied in the United States as evidenced by recent national assessments. In fact, the same percentage of girls and boys are taking all types of mathematics courses through the first year of calculus (Huang, Taddese, & Walter, 2000). The only statistically significant difference in course taking was found in advanced placement calculus, where girls represented only 41% of those who took the higher-level Calculus BC exam in 2008 (College Board, 2008). Girls are also earning the same grades or higher than boys in mathematics at all grade levels (Byrnes, 2005). In addition, on the 2005 Grade 12 National Assessments of Educational Progress (NAEP) for math, girls and boys earned nearly identical scores on measures of mathematical concepts and computation (Byrnes, 2000). Similar studies, using both international and national data samples have had similar findings (Catsambis, 1994; Hanna, 2003).

Despite this gender parity in mathematics achievement, women continue to be underrepresented in math and science, especially engineering and computer science, in both higher education and in the workplace (Lynch, Leder, & Forgasz, 2001; Besecke & Reilly, 2006). While there is an almost equal number of men and women earning bachelor's degrees in mathematics, women are conspicuously absent from graduate programs in mathematics. According to a recent survey conducted by the National Science Foundation (2007), women earned only 27.1 % of all mathematics doctorates awarded in 2005. However, when breaking those statistics down by United States citizenship, the numbers are even more startling, as U.S. women earn only 12.6% of all of the mathematics doctorates awarded. Unsurprisingly, there is also a dramatic lack of female faculty in college and university mathematics departments, with only 13% of the total doctoral faculty in mathematics comprised of women in 2003 (Kirkman, Maxwell, & Rose, 2004).

Catsambis (1994) found that clear gender differences in career aspirations and interest in math develops by early middle school. She suggests that girls take math and sciences classes to meet college acceptance requirements, but that they may be "reluctant participants in mathematics learning" (212). In her study, female students tended to have less interest in mathematics and less confidence in their abilities, despite their overall higher achievement than boys. Besecke & Reilly (2006) in their study of the key factors involved in students' career choice, found that "by 12th grade, males consistently have more positive attitudes than females about mathematics and science" (Besecke & Reilly, 2006, 11).

Similarly, in their survey of 2,213 seniors, Dick & Rallis (1991) found that among men and women who were taking both physics and calculus, the proportion of men choosing a career in science or engineering was much greater than the proportion of women doing the same. So, girls who are taking and excelling in courses that will supposedly allow them to enter high paying math and science careers are still not choosing those fields. Therefore, "keeping open the door of opportunity to these careers does not guarantee that they will pass through it" (Dick & Rallis, 1991, 291). It seems clear that girls disinterest in and dislike of mathematics develops independently of students' learning opportunities and achievement level. Boaler (1997) argues that girls resistance to math is not because they think they aren't good at it, but because "they want to be able to understand mathematics and they won't accept a system which merely encourages rote learning of symbols and equations that mean little or nothing to them" (Boaler, 1997, 300). Even the girls who are succeeding in the mathematics classroom are not happy to be there and very few see themselves entering a math or science career in the future.

This decline in interest, despite comparable academic achievement may be related to differential treatment of boys and girls in mathematics classrooms. In a classic study of boys' dominance of classroom interactions, Sadker & Sadker (1994) found that boys control the linguistic space of the classroom in a variety of ways. First, they ask more questions, answer more questions, and are more likely call out responses without being reprimanded. They receive more praise, and more importantly, more specific and constructive criticism from their teachers. Girls get rewarded for being quiet, are more likely to get reprimanded when they are assertive, and less likely to receive feedback on their schoolwork. These gendered experiences can lead to a perception of math as a male domain.

In the past, efforts to increase girls' and women's participation in mathematics have focused on "chang[ing] girls so that they are more compatible with mathematics" rather than to "chang[ing] mathematics so that it is more compatible with girls" (Campbell, 1995, 225). However, changing the girls without changing the environment that created the girls' dislike to begin with will never be an effective long-term solution.

Feminist Theory

Adapting a model first introduced by McIntosh (1983), Kaiser & Rogers (1995) describe the five phases of gender reform in mathematics. In the first phase, women were absent from mathematics. Theorems were named after men, the language used in mathematics instruction was masculine, and examples used to illustrate content were based on male experiences (Kaiser & Rogers, 1995). In phase two, women mathematicians were seen as "exceptions," using a "famous few" approach that relegated women to "loner status" in mathematics (Kaiser & Rogers, 1995). Phase three demonstrated a conceptual shift in seeing mathematics as appropriate for all women. During this phase women were viewed as a problem or as victims who needed to be helped. Widespread intervention programs were developed to give women the skills to "work within the system" to be successful in mathematics (Kaiser & Rogers, 1995). According to Kaiser & Rogers, we are currently in the transition between phase three and phase four, in which women will be viewed as central to mathematics (Kaiser & Rogers, 1995). The centrality of women in mathematics would lead to phase five, which is "mathematics reconstructed." Women would be empowered to change the discipline and to change mathematics as a field (Kaiser & Rogers, 1995).

This history of women's role in mathematics closely parallels the history of the women's movement and feminist theory. Early on, liberal feminists and educational researchers focused on removing the barriers that denied women access to mathematics and mathematics careers. This was based on the belief that if women and men had the same educational opportunities and the same rights and access, then that would result in gender equality. Once formal legal or structural barriers were removed, however, women were still underrepresented in mathematics. The focus then shifted to research on sex differences in mathematical ability (Fennema, 1974; Fennema & Sherman, 1978; Benbow & Stanley, 1980). Women's behaviors were compared to the behaviors of men, deficits in skills and aptitudes were identified, and programs were created to remedy those deficits. The behaviors of successful men in mathematics were taught to women. Those programs, which are still popular today, focus on providing girls and women with the skills and attitudes they need to be successful in the mathematics field (Lacampagne, Campbell, Herzig, Damarin, & Vogt, 2007). However, what is problematic about this intervention approach is the fact that those skills and attitudes that are deemed "necessary" are the ones possessed by men. Men are the gold standard to which women are constantly measured.

Difference feminism, also known as cultural feminism, developed in direct response to liberal feminism (Mura, 1995). The term "difference feminism" frequently refers to feminists who criticized liberal feminists for ignoring the differences between men and women, and more importantly, for advocating that women become more like their male counterparts (Tong, 1998). Difference feminists believe that in order to end women's oppression one must acknowledge that men and women are different, with different ways of thinking, based on different experiences in the world (Gilligan, 1982; Belenky, Clinchy, Goldberger & Tarule, 1986; Becker, 1995). Rather than viewing women's differences as weaknesses or deficits, and encouraging women and girls to change, difference feminists believe that we must equally value women's ways of knowing and doing (Salomone, 2003). They argue that the existence of gender differences is only problematic because a hierarchy exists that values male qualities and behaviors over female ones.

Radical feminists find the arguments made by difference feminists problematic, arguing that such claims perpetuate gender stereotypes and inscribe those traits on women (Tong, 1998; Salomone, 2003; MacKinnon, 1989). They also find fault in the fact that the source of those differences is ignored, claiming the question is irrelevant, and thereby making the differences appear “natural” instead of socially constructed. While radical feminists agree that using men as the standard by which women are always compared is insufficient, they don’t believe the focus should be on “celebrating” women’s differences. In fact, they argue that placing so much emphasis on the “difference question” only serves to distract from the more substantial issues in mathematics education (Salomone, 2003). Ironically, such research that aims to improve gender equity in mathematics, has had the opposite effect of “proving’ women’s inferiority in mathematics. Instead, radical feminists argue that the field of mathematics itself should be examined, and women’s behaviors within it. Just because men and women behave differently in the field, does not mean that women are “weaker” or less mathematically able than men. Rather, research should examine how the field was created, who decides what is valued within the mathematical community, and question the taken-for-granted assumptions of the field itself.

Feminist Standpoint Theory

The concept of a “feminist standpoint” originates from the work of Nancy Hartsock (1983), and is rooted in the Marxist idea of the proletarian standpoint (Damarin, 1995). Feminist standpoint theory has evolved from the idea that women are in a better position to criticize the field of mathematics because of their marginalized status in the field thus far. “Women can know the world in valid ways that are not available to their oppressors; because they have less to lose in changing the status quo, they are less bound to it and better able to examine it ” (Damarin, 1995, 247). As outsiders or relative newcomers to the field, it will be easier for them to be critical of what is taken-for-granted as normal and natural in the field.

> Because women (and other “marked” groups) bring to their study less investment in continuing current theories, conceptions, and practices, their relations to the objects of study are less bound to the acceptance of present understandings as “true” or “natural.” Indeed, the idea of the “natural” is rejected. Thus, the feminist-standpoint idea allows for a multiplicity of truths, none of them complete, and finds most valuable those investigations that begin with the lives of women (Damarin, 1995, 248).

The goal of feminist standpoint theory is not to reverse the gender hierarchies in mathematics or to valorize women’s ways of knowing over men’s ways of knowing. Such an act would merely reinforce the existing gender binaries and hierarchy, rather than attempting to eliminate hierarchies all together (Foucault, 1990). Feminist standpoint theorists argue that while such a stance will inherently improve the situation of women in mathematics, it will also enable change that will make mathematics more accessible for all students (Damarin, 1995).

In 2005, only 1% of all bachelor’s degrees earned were in mathematics (NSF, 2007), which means that a large percentage of the population is not choosing mathematical careers. This suggests that the field of mathematics needs to change. Underlying my theoretical framework is the belief that if mathematics as a field needs to change, which statistics seem to reveal that it does, it is through the eyes of women that researchers can most clearly see mathematics and begin to question it. It is through understanding women's experiences in mathematics that researchers (and women themselves) can begin to understand what it is that makes the discipline so uninviting for the majority of the population.

Theoretical Framework

Introduction

My theoretical framework builds upon the work of poststructuralist Foucault (1990, 1995), and radical feminist MacKinnon (1989). Although their theories are seemingly incompatible at first, their ideas about social power and the social construction of gender are useful for examining this issue of women's under-representation in mathematical careers. For,

> A major part of this experience for many women is indirect; that is, the experience of mathematics does not take place within a community of creators or users of advanced mathematics, but rather in the general society. This experience is primarily discursive, not active, which is to say that the relation of most women to mathematics is constructed by the receipt of messages about mathematics. Thus, it is the content of these messages that creates the experiences (Damarin, 1995, 250).

While in form their theories vary significantly, both Foucault (1990, 1995) and MacKinnon (1989), share some common assumptions about the social world:

a. There is no one universal "truth", but instead there are multiple truths

b. Identity (including gender) is socially constructed, thus our consciousness is determined by social norms

c. Deconstruction of various knowledge claims or taken-for-granted assumptions is a primary tool for social change

There are two hallmark concepts of post structural theory. First, poststructuralists do not try to create grand theories or see history as a story of progress. Foucault (1990), like others, believed that science was using metanarratives as a source of legitimation, and in the process, have created hierarchies of knowledge (Seidman, 2004). In the eyes of poststructuralists, the identification and categorization of science is unrealistic. Our world is too heterogeneous to fit into such neat categories, and those who do not fit are then excluded.

The second guiding concept of post structuralism is the idea that we can never capture reality, because it is always changing and always situated in the knower. Therefore, the value of post structuralism "lies in neither producing liberating truths nor socially useful knowledge. The value of postmodern science consists in making people more aware and tolerant of differences, ambiguity, uncertainty, and conflict" (Seidman, 2004, 172).

Poststructuralists are also very concerned with the effect the knowledge that they create will have on the social world. They use deconstruction as their primary method to examine the relationship between knowledge and power, and to uncover the instability of the social world. "Deconstruction aims to displace the hierarchy, to render it less authoritative in the linguistic organization of subjectivity and society" (Seidman, 2004, 169). In particular, deconstruction focuses on examining the binary structure of language and disrupting it. This can be accomplished in three ways. First, deconstruction can reverse the binary structure. Second, it can blur the boundaries between them. Finally, deconstruction can "highlight moments of contradiction and undecidability in what appears to be a neatly conceived structure or text" (Gibson-Graham, 1999, 8).

Discourse

Foucault differed from many modern theorists in his focus on micro-level analysis. He spent a great deal of time researching smaller social units such as hospitals and prisons, using an inductive approach to social analysis (Foucault, 1995; Seidman, 2004). This bottom up approach allowed Foucault to study the most common sites of social conflict, the ones that tend to be overlooked by more totalizing theories.

Power was clearly a focus of Foucault's work. He asserted that in postmodern times, power is not the power of the sovereign or state over its subjects. Instead, in what he calls a "disciplinary society," order is maintained "through technologies such as spatial separation, time management, confinement, surveillance, and a system of examinations that classify and rank individuals for the purpose of normalizing social behavior" (Seidman, 2004, 189). In such a society, the individual is always visible because of these techniques of surveillance, and it has the effect of the individual disciplining or regulating him or herself. This constant "discipline" has the effect of normalizing behavior, but it also results in increased individuality because deviance is more highlighted in such a regulated environment.

Central to this concept of disciplinary order is the idea that social norms are not only accepted or adopted, but they are embodied. In other words, "power is embodied when certain forms of behavior feel right to us, when our bodies "naturally" take on the correct position for a certain situation" (Chambers, 2008, 23). The repetition of specific disciplinary practices, such as female appearance norms, becomes habitual. Once habitual, they appear natural, rather than self-imposed. According to Foucault (1995), such behaviors are reinforced through a fear of surveillance by others. Of course, the very existence of social norms is not necessarily problematic. In fact, without social norms, it would be very difficult to exist in communal groups without chaos. In many ways, social norms make life easier and safer, since we know what to expect from ourselves and from others. What is confining and problematic about social norms is that they inevitably create hierarchies. For example, it would not necessarily be problematic that social norms for women were to be collaborative and men to be independent, except for the fact that the male norm of independence is more valued in our society, and thus the women's norm of collaboration is devalued.

Foucault (1990) argued, "The scientific disciplines shape the dominant ideas about who we are, what is permissible, what can be said, by whom, when, and in what form" (Seidman, 2004, 181). In his attempt to de-privilege scientific knowledge, he paid particular attention to discourse. Discourse, by Foucault's (1990) definition, refers to bodies of knowledge, such as the academic disciplines or social institutions. He believed that discourse "constrains —but also enables—writing, speaking and thinking within such specific historical limits" (McHoul & Grace, 1993, 31). Rosenberger (2003) elaborates on how discourses limit our behavior when she says, "as individuals we act and speak in the context of the discourses available to us in the communities that constitute our lives" (Rosenberger, 2003, 33). Foucault (1990) attempted to show the relationship between discourse and truth, in his effort to expose the "historical specificity—the sheer fact that things could have been otherwise—of what we seem to know today with such certainty" (McHoul & Grace, 1993, 33). In this way, scientific research and the media have the effect of producing what Foucault (1980) calls "regimes of truth" (131). In the following section, I will describe how I believe there are five competing discourses that are created through discursive formations that have the effect of creating “regimes of truth” about women’s mathematical ability and women’s role in mathematics. What is believed to be “true” about women’s math ability determines what is essentially possible for women, limiting their conceptions of their own abilities, and ultimately limiting their behavior.

Foucault (1990, 1995) never actually wrote about the gender gap in mathematics. In fact, he was heavily criticized by feminist theorists for ignoring gender in his theories of power (Bartky, 1988). However, Foucault (1990) did write extensively about sexuality, and was particularly interested in the way that sex was put into discourse—who is doing the talking, and what they are talking about. In this paper, I will undertake a similar task, examining which discourses play a role in girls’ experiences with mathematics, how those ideas have been put into discourse, and the normalizing effects those discourses have on society in general, and girls in particular. Using some of Foucault’s methods of deconstruction, I hope to begin the process of disrupting the normalizing role of the mathematics gender gap discourse, and to understand more deeply the experiences of girls’ and women in mathematics.

Competing Discourses for Women in Mathematics: A Theoretical Model

Discourses do not exist in isolation, nor are they static. By their very nature, discourses are constantly being created, maintained, or challenged through discursive practices (Foucault, 1990). For example, what it means to be a female in our society is constantly being contested or reified through discourse. Within one individual interaction, gender norms can be simultaneously maintained and challenged. But, perhaps more importantly, a multitude of discourses are constantly operating at any given time, often times competing or complementing one another. For example,

> Simultaneously told that it is important to learn mathematics, and that it is not important (for girls and women) to learn mathematics, women are subject to a multitude of other mixed messages about the importance of mathematics in their lives (Damarin, 1995, 250).

Thus, the social construction of gender is inextricably linked with mathematics, as gender norms influence the nature of mathematics, and mathematics reinforces the social construction of gender. To look at one discourse without the other would provide an incomplete and partial explanation of the phenomena in question, for it is impossible to know how one would exist differently without the other. Both women and men receive messages about mathematics being a male domain, a message that is derived simultaneously from gender discourses and mathematics discourse. Therefore,

> Regardless of how mathematically competent a woman becomes, she can never escape discursive practices that reify the idea that mathematics is, indeed, a male domain. Thus, for a woman to continue to learn and to do mathematics, she must continually reject the messages that connote her “natural” position (Damarin, 1995, 250).

This concept of competing discourses or messages about societal norms is not new. In fact, many researchers have made similar points about how the nature of mathematics is socially constructed, or how gender roles are reinforced through discursive practices (Bartky, 1988). However, what is lacking is a theoretical model that is capable of exploring several of these discourses simultaneously, explaining how those discourses dialectically interact to create a social phenomenon. In particular, I am interested in creating an explanatory model that will identify the discourses that play a central role in the experiences of girls and women in mathematics, and how those discourses, as they are maintained and challenged, elicit certain responses from individual women.

When examining the experiences of girls and women and their relationship to mathematics, I believe there are five primary discourses that directly influence their decision to enter a mathematical career (see Figure 1). The five discourses are: 1) mathematics (D1), 2) math ability (D2), 3) math power (D3), 4) math deviance (D4), 5) sexuality (D5). Each of the five discourses is constantly changing and being influenced by the other four discourses in this model, as altering one of the discourses in this model can have a modest impact on the other discourses. It would make sense, for example, that the sexuality discourse heavily influences what is consider deviant or powerful for women. Since mathematics was created and continues to be dominated primarily by men, it is heavily influenced by the sexuality discourse as well. In the following sections, I will describe and provide examples of each of the five discourses, explicating how those discourses are interrelated and entangled to create a complex web of messages about mathematics and gender.

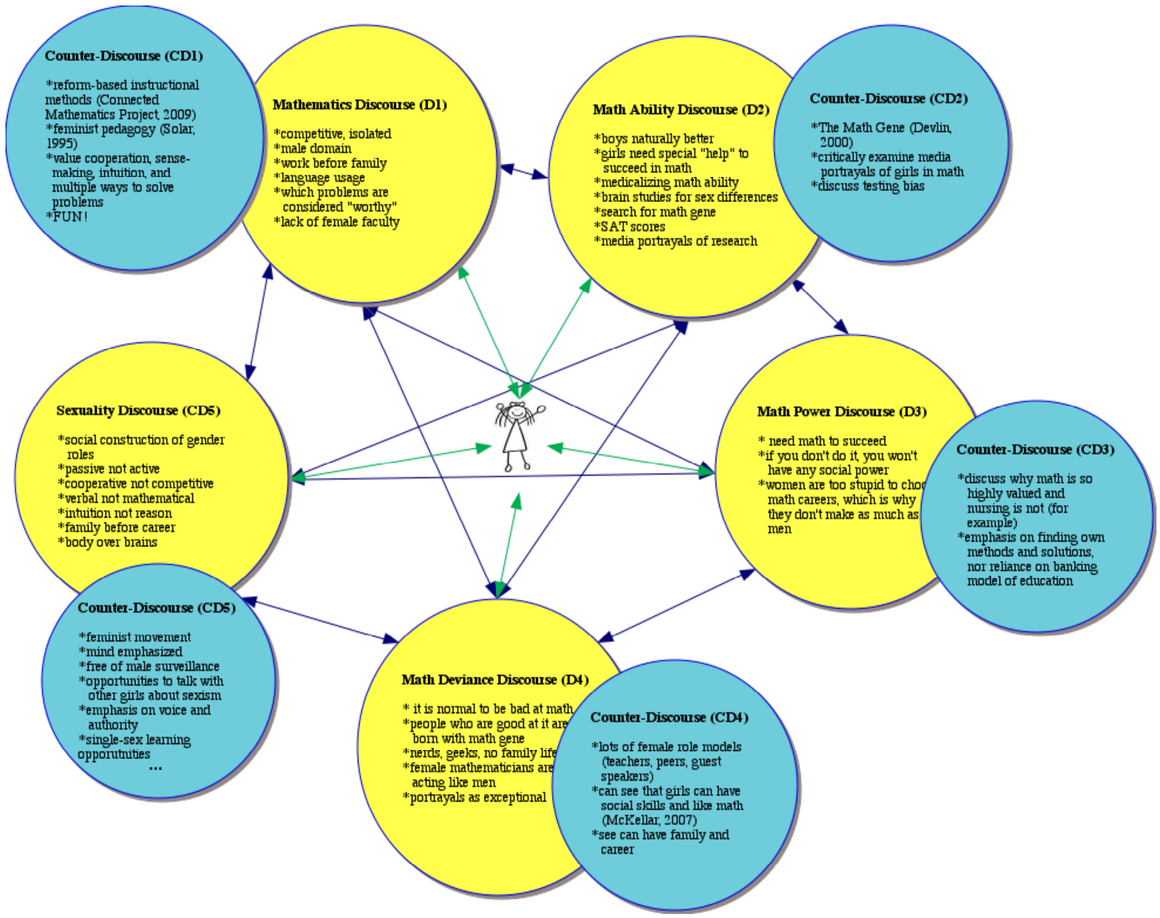


Figure 1. Competing Discourses for Girls and Women in Mathematics

Discourse 1: Mathematics

In order to understand the discourses surrounding girls and women in mathematics, one must first examine and interrogate the normalizing discourses of the discipline itself (see D1 in Figure 1). In the United States, mathematics is seen as an objective body of knowledge that is value-free and unchangeable (Stanic, 1989). Math is not seen as political or social or socially constructed—math is just math. The traditional way that mathematics is taught in school is one way that this discourse about mathematics gets produced and reproduced.

> Mathematics tends to be taught with a heavy reliance upon written texts that removes its conjectural nature, presenting it as inert information that should not be questioned. Predominant patterns of teaching focus on the individual learner and induce competition between learners. Language is pre-digested in the text, assuming that meaning is communicated and is non-negotiable (Burton, 1995, 276).

The practices in mathematics can be understood as "discursive formations", in which what "counts" as legitimate mathematical knowledge and successful participation is produced (Foucault, 2002, 34). In that way,

> Nonconformity is consequently not just a feature of the way that an individual might react as a consequence of her or his goals in a practice or previous network of experiences. The practice itself produces the insiders and outsiders…highlight[ing] the subtle and not so subtle ways in which those situations have excluded others by virtue of the manner in which those workplaces and their practices are constituted (Lerman, 2004, 27).

In other words, the very way that mathematics is structured, conducted and discussed will influence who becomes a mathematician and who does not.

Foucault (1995) makes several references to the similarities between penitential practices and the operation of schools. Specifically, he discusses Bentham's (1995) "panopticon" as a symbolic form of surveillance that regulates and controls behavior. The panopticon itself was a cylindrical observation tower centrally located with prison cells evenly spaced around it. This structure, with its one-way mirrors presented the possibility of constant surveillance. According to Foucault (1995), this possibility of surveillance led the prisoners to "self-surveil" resulting in high degrees of conformity and docility. While most schools are not arranged as panopticons in structure, they are in function. Each classroom is arranged laterally, and can be easily surveilled. The teachers themselves are isolated from one another, as are the students, divided and arranged by age, grade, subject, and ability. Students are surveilled by their teachers, and by each other, as peers frequently tattle on each other, thus normalizing and regulating behavior. Students and teachers alike become self-regulating, matching their behaviors to the expected norms of the school (Foucault, 1995).

Math classes, in particular, tend to be highly regulated in this manner (Boaler & Greeno, 2000). Students often sit in rows, facing the teacher, while in other disciplines the seating is more informal. Teachers spend a great deal of time modeling the various mathematical procedures for students, indicating precisely where to place the next digit, how to record their work, how to circle their work, etc. Worksheets have boxed off areas to indicate where to put a particular step or numeral, and pre-determined steps are emphasized. Accuracy is highly valued in most mathematics classrooms, implying that there is, indeed, only one correct answer to any given problem (Stigler & Hebert, 1997). In addition to accuracy, speed is also encouraged by the use of timed multiplication tests, and competitive racing games like "Around the World," where the goal is to be the first one to correctly answer a mathematics question when paired with each of the other students in the class. In games like those, what is emphasized is not reasoning, but instead, computational speed.

Math, more than any other subject, is rarely taught in the context for which the skills are used (Boaler, 1994). In one study of instructional practices in the U.S., Germany, and Japan, it was discovered that in U.S. classrooms, teachers focus on demonstrating how to do a mathematical task, while the Japanese teachers' goal was to enhance conceptual understanding (Stigler & Hiebert, 1997). As a result, students in the U.S. are taught a series of complex steps or rules to follow, and a strong emphasis is placed on symbolic or abstract representations of problems. When learning new concepts, students are quickly pushed into using those symbolic representations, before they ever understand what the symbols represent. Therefore, mathematics becomes a mind-boggling mental exercise in the memorization and manipulation of variables and numbers. Even when presented with "word problems" or "story problems" those situations are rarely realistic, and rarely applicable to the actual lives of students (Boaler, 1994). From these experiences students recognize their lack of conceptual understanding and rather than see mathematics as a powerful tool see it as the application of useless rules on trivial "puzzles."

Work in mathematics class is often individual, which encourages competition between students. Sticker charts and elaborate scoring systems are used to publicly record and rank students based on their achievement and ability. In some schools, there has been an increasing use of electronic Personal Response Systems (PRS) that each student uses to indicate their answer to a given question. The students' responses are projected on a screen and the distribution of correct and incorrect responses is often displayed in a histogram. In this way, each student in the room knows how they compare to every other student, and their answers to each problem are surveilled. The PRS is professed as a cutting edge tool to be used for formative assessment, one that will allow teachers to more easily identify students' areas of weakness and be able to address misconceptions and give individualized attention (McConnell, Steer, & Owens, 2003). Foucault (1995) would argue that this type of technology is just another way to control and regulate students' behaviors.

Although boys and girls are usually educated in the same classrooms, they do not have the same mathematical experiences in those shared spaces. As mentioned previously, boys tend to dominate instructional time in mathematics classrooms (Sadker & Sadker, 1994). They are more likely to get called on, more likely to call out, more likely to dominate supplies and group work, more likely to receive criticism, and more likely to receive praise. While girls are performing just as well academically, they are much more likely to play a passive role in mathematical discussions and activities (Sadker & Sadker, 1994). In the minds of both boys and girls, this creates an image of boys as being "better" at math and more "natural" mathematicians.

In addition, as discussed previously, the majority of mathematics faculty in colleges and universities are men (Kirkman, Maxwell, & Rose, 2004). In a study of female graduate students in mathematics, Lacampagne, et al., (2007) found that there is a tendency for faculty to mentor students of their same sex. Because there is such a lack of female faculty in mathematics departments, this may put women at a distinct disadvantage when it comes to mentoring. It may explain why several studies have found that women receive less mentoring than men in graduate school (Berg & Ferber, 1983; Hollenshead, Younce, & Wenzel, 1994).

Finally, each discipline has a dominant style of communication that is preferred or accepted. In mathematics, that communication style is characterized as highly competitive, confrontational, and argumentative (Burton, 1995). "Because of their socialization, female graduate students' styles of interaction may be different from those expected by male faculty; those behaviors may be misinterpreted as inferior, rather than different" (Lacampagne, et. al, 2007, 245). Since the "girl problem" in mathematics has been identified, it has been taken-for-granted that this style of communication has been normalized as the only way that mathematics can or should be conducted. Therefore, the onus is placed on women to adopt this style of communication, for, if they do not, they are unlikely to succeed in the field. However, in recent years, mathematics educators have begun to question why such a style of communication is so valued within the discipline, and why other styles of communication are so devalued in mathematics, and in society as a whole (Becker, 1995; Boaler & Greeno, 2000) .

These discursive practices create a discourse about the nature of mathematics. More specifically, it creates an image of what "counts" as valid mathematics practice, what it is used for, and who should engage with it. Since most people do not feel that mathematics is something desirable to engage in (NSF, 2007), this seems to be a discourse of exclusion.

Discourse 2: Math Ability

Deeply connected to this general discourse of mathematics is the discourse of mathematical ability (see D2 in Figure 1). In other words, who is deemed mathematically able is going to be related to how mathematics is defined and what "counts" as doing mathematics. Historically, the field of mathematics has been perceived as a male domain, and accordingly, men were understood to have superior math ability to women.

The search for sex differences in mathematical ability has a long and tenuous history. For, "even when researchers announce that a mathematical performance gap has been closed, some researchers seek sex differences in sub areas of the mathematics in question or in subgroups of the general population" (Damarin, 2008, 107). As a result, there is a pervasive belief that it is a "fact" that boys are better at and have more "natural" mathematical ability than girls (Hyde, Fennema, Ryan, Frost, & Hopp, 1990). And perhaps more than that, there is a belief that people are either born with a math gene, or they are not (Damarin, 2008).

Foucault (1990) did not see medical findings about sexuality as being liberating for individuals. Instead, he saw the medical knowledge that was produced and dispensed as regulating individuals as sexual objects. Such medicalization of sexuality defined what was normal and abnormal, thus creating a form of social control. In much the same way, the medicalization of mathematical ability has defined what is normal and abnormal, classified individuals as such, and then pronounced various “treatments” to address the “abnormalities.”

The sheer volume of medical research on alleged gendered brain differences is vast and astounding. The quest to determine if girls’ and boys’ brains differ at various stages of development has become a major industry. From these neuroscientific “discoveries,” arguments are made that girls and boys are fundamentally different, and thus should be treated differently (see Sax 2005). These type of “scientific” knowledges when put into popular discourse, ultimately create the types of gender differences that they are trying to prove exist.

Other research (Sanders, Soares, & D’Aquila, 1982; Benbow & Stanley, 1980) has suggested that boys have better spatial reasoning, and that certain parts of their brains, responsible for those types of tasks, are more developed in boys than in girls. There is very little discussion of the cause of those structural or functional differences and whether or not those gendered differences could be the result of differential socialization and experiences (Chipman, 2005). In addition, there is also no recognition of the fact that there is greater variability within gender than between genders on these types of tests. This, “prioritizing of a small but statistically significant difference over a large shared variance is a choice researchers often make when interpreting data” (Damarin, 2008, 107), and which ultimately serves to benefit the dominant group. These claims, which are based on inconclusive evidence, create an illusion of certainty and “naturalness” of mathematical ability.

The search for a so-called “math gene” is another example of this medicalizing of mathematical ability. Scientists have yet to find such a gene, but the rumor of its existence permeates the discourse on mathematical ability. Again, this idea of being “born with it” or without it, ultimately limits individual behavior. Those who excel in mathematics are viewed as possessing a rare genetic or biological predisposition for it. This provides a rationale for why there is such a lack of women and minorities in mathematics. For, perhaps they just don’t have the gene, or their brains are not structured in a mathematical way. It should not be surprising that it is socially acceptable in the U.S. to be bad at math, since the medical discourse reinforces the idea that math ability is biologically based, and thus is not something that can be changed.

In addition to the brain scans and genetic studies that are used to purport gender differences, population statistics based on standardized tests are used to argue that there is a gender gap in mathematics. The rational for these widely used standardized tests, especially in the age of No Child Left Behind, is to ensure equality and accountability. In other words, these tests, these forms of surveillance, are being used for the greater good of society. The tests are championed for not only providing information on how various school districts compare, but it also allows educators to identify “high needs” students (Massachusetts Department of Education, 2009). These students, based on their poor results on standardized tests, are frequently referred to "specialists" and identified as learning disabled. They are then separated from the rest of their "normal" peers and "treated." While many high schools have decided to move away from tracking students by ability in most subjects, mathematics continues to be heavily tracked, both formally and informally, in almost every secondary school in the United States (PROM/SE, 2008).

While these standardized tests may seem beneficial for identifying differences in achievement based on gender, race, or class, they also have the impact of normalizing those behaviors and reinforcing stereotypes. In other words, by repeatedly identifying low-income minority girls as underperforming in mathematics, we are not only reporting on a difference that exists, but we are reproducing that difference through this type of discourse.

The fact that standardized tests are called "standardized" is also significant. One of the common beliefs about those tests is that they are "objective" and are capable of showing relative ability, as peers are compared to one another. Thus, it is possible to know exactly how one student did in comparison to the rest of the population, and deduct from that information whether they know more or less than the average. However, there is little consideration for the fact that these tests are socially constructed, and therefore can never be completely objective or value-free. Each test question that is selected is demonstrating a valuing of one type of knowledge over another. And further, the wording and context of each question is ultimately privileging certain types of knowledge over others. This is why opponents of these tests argue that they are inherently biased. For, "the lower performance of certain groups on measures of cognitive processes reflects cultural differences embodied in the contexts of the assessments rather than real deficits in some basic area of cognition" (Stanic, 1989, 63). The dominant group has created these tests and has determined what is considered socially valuable knowledge, so it would make sense that students who are members of that dominant group would perform better than those outside the group.

After this scientific knowledge is produced, the media plays an important role in the reproduction of sex differences in mathematical ability. Not only is there a selection process involved in what is worthy of scientific study, but there is also a selection process for what is considered newsworthy or fit to print. Thus, even when studies find only small differences in mathematical ability and are reported as such, the media often takes that small difference out of context, purporting major differences in mathematical ability. How those differences are reported in newspapers and on television programs will dramatically influence the messages being sent about gender differences, what skills are valued, and who possesses those valued qualities. In an older study, Jacobs and Eccles (1985) found that parents' perceptions of their child's math ability were directly influenced by the media. Specifically, parents who had filled out a survey about their child's math ability were resurveyed after a report on sex differences in mathematical ability (Benbow & Stanley, 1980) had been released and presented in many different print media. The news reports clearly suggested that there was "proof" that girls were not as mathematically able as boys, and implied a genetic cause. The researchers discovered that mothers who had read the news reports reported a decline in their perceptions of their daughters' mathematical ability, while mothers who were unexposed to the reports did not (Jacobs & Eccles, 1985).

It seems clear that there is a powerful discourse that perpetuates the idea that significant sex differences in mathematical ability exist. Even when statistics have proven otherwise, researchers and news reporters continue to send the message that boys are better at mathematics. There appears to be a compelling preoccupation with finding and reporting sex differences in mathematical ability. Damarin (2008) argues that it is because “the identification of sex-gender (or race) differences tends to serve the interests of the dominant group, if only because the groups in power produce the constructs on which the measurements are based” (107). Regardless of the reason, the messages have permeated our society, despite scientific evidence that refutes the truthfulness of those messages.

Discourse 3: Math Power

While the math ability discourse perpetuates the idea that girls are not as skilled at mathematics, there is an opposing discourse that sends girls the message that they need math to be powerful and successful in the world (see D3 in Figure 1). Math is portrayed as a gateway to high status, high paying occupations (NCTM, 2000), and girls’ underperformance in mathematics has been identified as a reason why women still do not make as much money as men in the workforce. However, according to Stanic (1989),

> Using a slogan like “mathematics is a critical filter” to argue for the need for greater equity can serve to legitimate existing social arrangements. Our society has a long and unfortunate history of erecting artificial barriers, or using filters, to limit access to positions of power (69).

It is taken for granted that careers that require mathematical skills will be high paying and high status. In fact, in 2003 the average salary of an individual with a master’s degree working in a math, science or engineering career was 17% higher than the average salary of those working in non-SES careers (NSF, 2007). But, instead of questioning why mathematics is so highly privileged over other subjects in U.S. society, girls are simply encouraged to go get those types of jobs so they can earn equal status and equal pay. However, when examining that data more closely, it becomes clear that while there is a significant pay differential between SES and non-SES careers, there is also a significant difference between what women and men earn at all educational levels in both the SES and non-SES jobs (NSF, 2007). In fact, of the population of college-educated full-time workers, women who were ten years out of college earned only 69% of men in the same category in 2003 (AAUW, 2008). Thus, even when women are entering careers requiring mathematical skill, they may be earning more than they would in a non-SES field, but they are still consistently making less than their male counterparts.

According to the media, the formal barriers to participation in mathematics have been removed. Instead, the focus has shifted to the existence of sex-role stereotypes that define what an acceptable career path is for girls. Some researchers argue that girls are experiencing peer pressure and "parental suspicion" if they demonstrate an interest in mathematics or science (Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005). Recently, the blame for girls' absence from mathematics has shifted to the girls themselves (and their parents). Women are admonished for not recognizing the importance of mathematics and not attempting overcoming the initial obstacles they face (Lynch, Leder & Forgasz, 2001). With this logic, math is accessible and good for girls, and girls are just too stubborn or stupid to figure it out. This deficit discourse, which claims that girls lack self-confidence (Greenberg-Lakes, 1990), have math anxiety

(Tobias, 1993), or simply have inferior mathematical minds, serves to reinforce the valuing of mathematics and male superiority simultaneously.

This issue of girls' underperformance in mathematics has been heavily researched and publicized, focusing primarily on how boys' and girls' participation and achievement differ, and arguing about how best to "bring girls up" to the boys' standard. In this dialogue, boys and men have clearly defined the norm for which girls should strive to achieve. Special programs have been designed to increase girls' participation, all the while assuming that there is nothing wrong with math, and that if girls would only overcome their misconceptions and fears about mathematics, they would be successful.

> Almost all of this research takes as unquestioned and even as axiomatic the universal desirability of mathematical ability; that is, the research is driven by assumptions that when women (and others) fail either to become mathematically able or to embrace that ability when they have it, it is not because mathematics is undesirable, but due to some other factor (Damarin, 2000, 69).

Instead, perhaps the real "truth" is that girls are making an informed decision not to enter a field that is alienating and irrelevant to them. And rather than encourage girls to enter such a field, perhaps the goal should be to encourage girls and women to question why mathematics is so valued over other disciplines.

Discourse 4: Math Deviance

Many of the programs that have been created to increase girls' participation in mathematics are derived from the discourse that mathematical knowledge is necessary to acquire social power. However, according to Damarin (2000), this is a minority view that is opposed daily in the media and social interactions. Instead, there is an opposing discourse that sends the message that being mathematically able is rare, and thus, a form of social deviance (see D4 in Figure 1). For, deviance only exists in relation to what is considered normal in the larger group. According to Giddens (2006), there are two forms of deviance, “primary deviance”, which refers to a behavior that breaks a norm or law, and “secondary deviance”, which involves the labeling of the individual as a deviant (800-801). Therefore, those individuals who demonstrate skill or interest in mathematics are perceived as deviants, and labeled as such, since it is commonly understood that most of society is not good at and does not like mathematics.

Today, it is socially acceptable, or “normal” to be bad at mathematics. Failure in mathematics is rarely a cause for embarrassment, while an inability to read would simply not be acceptable. Reading and writing are seen as natural abilities that we are all born with and are expected to be able to do. Mathematics, on the other hand, is seen as a skill that only a small percentage of the population possess. In fact, the NCTM (2000) Principles and Standards for School Mathematics, addresses this issue directly:

> The vision of equity in mathematics education challenges a pervasive societal belief in North America that only some students are capable of learning mathematics. This belief, in contrast to the equally pervasive view that all students can and should learn to read and write in English, leads to low expectations for too many students (12-13).

While it may be true that being mathematically able is rewarded financially in our society, it is not rewarded socially. Mathematicians are portrayed in textbooks and in the media as exceptional, eccentric, and often socially incompetent (Damarin, 2000). These “nerds” are viewed as abnormally smart, but socially isolated, having given up their social lives (and families) in the pursuit of mathematical greatness.

This discourse of deviance is directly related to the discourse of mathematics itself. It should come as no surprise that people who willingly engage in a discipline that is viewed as competitive, irrelevant, and isolated will not be seen as normal. Because mathematics is viewed as abstract and removed from the real world, it makes sense that mathematicians would be seen in a similar light. Also, since math ability is perceived as something one is born with, it is not seen as something that is accessible to all. Finally, because the discourse of mathematics and math ability has constructed the idea that mathematics is male domain, women who demonstrate ability or affinity for mathematics are “doubly marked” (Damarin, 2008). Showing an interest in mathematics calls women’s femininity and sexuality into question.

Simultaneously, while women’s femininity is being called into question, she also exists at the margins of the mathematics community. Since mathematics is perceived as a male domain, and men are seen as having superior mathematical ability, a woman cannot be considered a “real” mathematician. And, if she does possess the same qualities as men within mathematics, she is somehow failing as a “real” woman by focusing too much attention on her career. This emphasis on maintaining womanhood is evident in the differential portrayals of male and female mathematicians. When women’s biographies are presented, there is a great emphasis on their family lives and the contributions that men have made to help them be successful (Nelkin, 1987). However, men’s biographies focus almost exclusively on the mathematical work itself, minimizing the importance of family or social relationships (Damarin, 2008).

It is impossible to know if women would be more likely to enter mathematics if there was not this discourse of deviance, but currently, they are doubly deviant in society when they do. One possible solution to this problem would be to make mathematical ability more socially acceptable in our society, which would require changing the image of mathematicians. In the early feminist movement, very few women willingly identified as feminists because they believed that only lesbians and extremists were feminists (Tong, 1998). In other words, they thought only deviants were feminists, and they did not want to be associated with such an image. One of the ways that feminists attempted to change that image, and continue to do so, it by having t-shirts made that said "This is what a feminist looks like." In a very public way, the previous misconceptions about feminism and feminists were exposed and challenged. As people began to see that "normal" people were feminists (and even some men!), more people began identifying as such. Perhaps a similar strategy would be successful to change the image of mathematicians.

Discourse 5: Sexuality

Underlying all four of the previously discussed discourses is the discourse of sexuality (see D5 in Figure 1). The way sexuality is talked about and put into practice, and the way gender is discussed in our society greatly influences the messages that get sent about mathematics and mathematics ability.

While difference feminists might see the gender gap in mathematics careers as caused by a devaluation of women's ways of knowing, radical feminist MacKinnon (1995) sees the problem differently. MacKinnon does not see "women's ways of knowing" as something to be proud of. Instead, she would argue that a women's unique voice "is not her own, but only what male supremacy has made it out to be" (Salomone, 2003, 59). In fact, she has said that women "exist as they do because of lack of choice. They are created out of social conditions of oppression and exclusion" (MacKinnon, 1995, 152). Therefore, she believes that our focus should not be on determining how similar or different men and women are, but rather, talking about power, dominance, and the gender hierarchy that currently exists in our society.

Specifically, MacKinnon (1995) believes that the root of male dominance is sexual. She argues that women's oppression is the result of men's control of women's sexuality, and that sexuality is a construct of male power, "defined by men, forced on women, and constitutive in the meaning of gender" (MacKinnon, 1995, 135). In her discussion of pornography, MacKinnon explicates how the pairing of dominance and masculinity and submission and femininity, not only represents, but creates sexuality and sexual difference.

> So many distinctive features of women's status as second class—the restriction and constraint and contortion, the servility and display, the self-mutilation and requisite presentation of self as a beautiful thing, the enforced passivity… This identifies not just a sexuality that is shaped under conditions of gender inequality but this sexuality itself as the dynamic of the inequality of the sexes" (MacKinnon, 1995, 137).

In other words, she believes that sexual difference and gender inequality are a function of sexual dominance.

As discussed previously, both MacKinnon (1989, 1995) and Foucault (1990, 1995) see gender roles as social constructs. In other words, the currently acceptable behaviors for males and females are the result of social practices, not biological differences. Girls are receiving messages about what it means to be female, and experience social consequences when their behaviors do not correspond with those social norms. In this way, femininity and masculinity are achieved through enactment of gender roles, or through gender performance (Butler, 1990) and should be viewed as "an artifice, an achievement" (Bartky, 1988, 64). What is important to consider, however, is that in our current system, a gender binary exists. Therefore,

> To have a body felt to be "feminine" –a body socially constructed through the appropriate practices—is in most cases crucial to a woman's sense of herself as female and, since persons currently can be only as a male or female, to her sense of herself as an existing individual (Bartky, 1988, 78).

This embodiment of social norms is central to Foucault's (1995) concept of disciplinary order. The women in U.S. society are not merely internalizing or accepting these social norms. They, as individuals, are constituted by these social norms.

Applying Foucault's (1990) method of deconstruction, Bartky (1988) examines how women's bodies are trained to be more "docile" than men's. Specifically, she identifies the various disciplinary practices that produce feminine bodies, which make femininity appear "natural." For example, she discusses women's constant dieting disciplines, the fact that they are restricted in movement and speech more than men, that they take up less physical space when sitting, walk with shorter strides, frequently avert their eyes, and give more smiles than they receive. In combination, these behaviors make up some of the seemingly natural distinctions between men and women. However, those behaviors have been learned over time. Women learn from the media, and their culture in general, to spend a great deal of time, effort, and money on beauty regimes such as hair and skin care. However, as Bartky (1988) points out, women are set up for failure in this effort, as the ideal they attempt to reach is impossible, and are ridiculed by men for their interest in such "trivial things." Women's bodies in contemporary U.S. society are under constant surveillance by the women themselves, other women, and men.

Through the various disciplinary practices, girls learn what it means to be female in our society. They are sent messages about women being "seen and not heard," about being submissive to men, and about their primary role as caregivers (Bartky, 1988). They learn that women are supposed to be more cooperative and less competitive than men. They are discouraged from being smarter or more aggressive than boys, and are praised for being quiet and passive, both at home and at school. And they learn that their bodies are more important than their minds.

While gender norms, like all norms, are constantly being revised, gender equality still does not exist. The messages that are being sent to girls about what is socially acceptable behavior for girls will influence the types of careers they are ultimately interested in. If girls learn that women should be cooperative, but they find mathematics extremely competitive, they will be less likely to enter that field. The incongruence between the gender norms for women in our society and the discourse of mathematics could explain at least some part of women's absence from mathematical careers. For, when girls and women enjoy mathematics, they are challenging traditional gender roles. In fact, a study has shown that girls with greater sex role stereotyping are less likely to enter mathematical fields (Armstrong, 1985).

However, just as Foucault (1990) argued that more sex would not be liberating for women because it would merely reinforce the sexuality discourse that served to control them, more math would not necessarily be liberating for girls. It should be recognized that while confining gender roles and sexism have limited women's role in mathematics, many girls are also making a conscious choice not to participate in a discipline that they do not see as relevant or personally rewarding. With this in mind, getting girls to like math in one context, but then placing them back in the same situation that they did not like will not lead to any long-term changes. Rather than trying to convince girls that they should like mathematics, consciousness raising should be used to help girls learn to be critical of their own mathematical experiences. Girls should be made aware of how they have been socialized by gender, while simultaneously encouraging them to be critical of mathematics. Currently, mathematics is a male domain, and is alienating to a large portion of the population. Failing to recognize that reality would merely reinforce the dominant discourses surrounding mathematical ability (Damarin, 1995).

Consciousness Raising

According to Foucault (1990), because power is everywhere, social resistance cannot be centralized. Instead, “social resistance must be heterogeneous; oppositional practices must be local, diverse, and specific to the social logic of their particular social field (e.g., prisons, schools, sexuality)” (Seidman, 2004, 190). Therefore, to move towards greater equality in mathematics, the discourse of mathematics must be to revealed and critically examined. Reversing the discourse or “feminizing” mathematics will only serve to reinforce the discourse that currently exists. Instead, we must “disturb the “normalizing” role of dominant discourses” (Seidman, 2004, 180).

One of the primary methods for achieving this, according to MacKinnon (1989, 1997), is through consciousness raising. Through such groups, women can become aware that they share certain experiences, such as their daily sexualization and fear of violence. For, “in consciousness raising, often in groups, the impact of male dominance is concretely uncovered and analyzed through the collective speaking of women’s experience, from the perspective of that experience” (MacKinnon, 1997, 67). In particular, single-sex schools could be seen as a potential site for such consciousness raising to occur. In such settings, not only would women be made aware of women's' historic absence from mathematics, but be able to share their own experiences and evaluate those experiences collectively. Finally, in a single-sex school, women would be freed from the surveillance by men, better able to form strong bonds with other women, and may be more likely to question and attempt to change the constricting gender role for which they have been assigned. For,

> The purpose of such consciousness raising would not be to tell us who we are, but rather to free us from certain ways of understanding ourselves, that is, to tell us who we do not have to be and to tell us how we came to think of ourselves in the way that we do (Sawicki, 1988, 86).

Counter-Discourses

Often, one of the outcomes of consciousness raising is the generation of counter-discourses. On this subject of counter-discourse, Foucault (1990, 1995) is often inconsistent. In the *History of Sexuality*, first published in 1978, Foucault (1990) suggests that there is no such thing as a counter-discourse when says,

> We must not imagine a world of discourse divided between the dominant discourse and the dominated one; but as a multiplicity of discursive elements that can come into play in various strategies. It is this distribution that we must reconstruct, with the things said and those concealed, the enunciations required and those forbidden, that it comprises; with the variants and different effects—according to who is speaking, his position of power, the institutional context in which he happens to be situated…" (Foucault, 1990, 100).

His stance that "there is not, on the one side, a discourse of power, and opposite it, another discourse that runs counter to it" (Foucault, 1990, 101) is a murky one. For, in an earlier work (Deleuze and Foucault, 1977) Foucault argues that "when those usually spoken for and about by others begin to speak for themselves, they produce a "counter-discourse"" (Moussa & Scapp, 1996, 89). Regardless of the terminology used, it seems clear that Foucault views discourses as both instruments and effects of power, but also as points of resistance (Foucault, 1990). According to Moussa & Scapp (1996), Foucault's theoretical work was politically motivated by his desire to "clear a space in which the formerly voiceless might begin to speak" (Moussa & Scapp, 1996, 89). By "clearing away" those oppressive discourses, it allows the counter-discourses that are created by those oppressed by a discourse to be heard.

By definition, these counter-discourses already exist, they are just overpowered by the dominant discourses. For example, feminist pedagogy is a type of counter-discourse that has been practiced for many years. A blend of liberatory and critical pedagogies like the ones described by Friere (1970) and hooks (1994), the goal of this type of pedagogy is to empower subordinate groups so that they might speak and act against the discourses that serve to reinforce social inequities (Solar, 1995). The use of a feminist pedagogy in a mathematics classroom is a strong example of a counter-discourse (see CD1 on Figure 1) to the mathematics discourse (D1) that dominates pK-12 and higher education today. For, a feminist pedagogy intentionally revalues certain processes that have previously been devalued in mathematics education. Solar (1995), analyzing the various themes in the literature on feminist pedagogy, identified the following characteristics:

1. breaking the silence and giving all women the right to speak
2. creating an appropriate learning climate for women, that is, a climate where competition is reduced and cooperation encouraged
3. changing the power distribution in the classroom in order to counteract domination and hierarchy
4. sharing feminist knowledge that ties to women's lives
5. valuing intuition and emotions as opposed to rationality and objectivity
6. taking experience as a source of knowledge
7. demystifying the construction of knowledge, its political value and the way women relate to it

8. revealing the omission of women and constructing a women's collective memory
9. working towards social change and giving women the means to do so
10. transmitting the necessary intellectual tools to build up a feminist critique
11. using verbal and written language which respects the experience and diversity of women
12. working towards the transformation of education (316).

If this type of pedagogy was effectively adopted by mathematics educators, it would not only change the way that mathematics is taught, but it would change the way mathematics is perceived, practiced, and discussed.

Another example of a discourse that counters the mathematics discourse (D1) is the recent proliferation of reform-based curriculums at both the elementary and secondary level. The definition of a reform-based curriculum varies depending upon the program using the definition. However, the term usually refers to an inquiry-based approach that emphasizes conceptual rather than procedural understanding (Riordan & Noyce, 2001). Each lesson is problem-based and rich in real-life contexts to which the students can relate. The students are the producers of knowledge, and the teacher adopts the role of facilitator or coach. The Connected Mathematics Project (CMP), developed by mathematics educators at the Michigan State University and funded by the National Science Foundation, is an example of this type of curriculum.

> Problem-centered teaching opens the mathematics classroom to exploring, conjecturing, reasoning, and communicating. The Connected Mathematics teacher materials are organized around an instructional model that supports this kind of teaching. This model is very different from the "transmission" model in which teachers tell students facts and demonstrate procedures and then students memorize the facts and practice the procedures (CMP, 2009).

This curriculum and others like it are offering a different way to learn and engage in mathematics. In contrast to the traditional method of mathematics instruction, students rarely work on problems alone, are constantly required to communicate their ideas, and are encouraged to use their creativity to find multiple ways to solve a problem or to represent a solution. But perhaps most importantly, students see mathematics as something that they do and create, as opposed to something that is memorized and applied in appropriate situations.

Finding a discourse that counters the taken-for-granted belief that most people are not born with the "math gene" and therefore are not good at mathematics was more difficult to find (see CD2 in Figure 1). In his book, ironically titled *The Math Gene*, Devlin (2000) provides readers with a persuasive argument for why most humans possess innate mathematical ability.

> Mathematicians are not born with an ability that no one else possesses. Practically everybody has "the math gene," just as practically everybody is born with two legs. We have it because the features of our brains that enable us to do mathematics are the same ones that allow us to make sense of the world" (Devlin, 2000, 267).

This book, written for the general public, attempts to debunk the myth that most of us can't do math because we weren't "born with it." Instead, he argues that we are all born with the ability and instinct to see patterns and relationships, and to have number sense. In an attempt to demystify math ability, he makes a comparison between marathon runners and mathematicians. He argues that most people are born with the ability to run, and that given the proper motivation, hard work, and training, most people could run a marathon. Similarly, he claims, most people are born with the ability to think mathematically, and therefore could become mathematicians.

Unfortunately, not all counter-discourses that emerge are liberatory or progressive. Such could be considered the case with proliferation of popular mainstream mathematics texts that have been geared toward girls' interests (McKellar, 2007).

Written by a young actress who was also an undergraduate mathematics major, *Math Doesn't Suck: How to Survive Middle School Without Losing Your Mind or Breaking a Nail* attempts to shatter the myth that girls can't do math (see CD4 in Figure 1). McKellar is an example of a visible and accessible female mathematician who is both "normal" and "popular" thereby making math ability seem less deviant. One of the strengths of the book is McKellar's repeated admonishment of girls for the common practice of "dumbing down" for boys and their peers. She sends a powerful message that it is ok to be smart and that in fact "smart is sexy" (McKellar, 2007).

However, despite those positive messages, the book simultaneously reinforces traditional gender roles. In an attempt to make the book appealing and relevant to young girls, there are constant references to beauty, mathematics problems that use stereotypical contexts (friendship bracelets, lipstick, shopping, babysitting, dating), and implicit heterosexism through the constant discussion of boys and boyfriends. McKellar's book offers an excellent example of the complicated relationship between the dominant discourses surrounding girls in mathematics. In her attempt to offer a counter-discourse for math deviance, she inadvertently reinforced the dominant sexuality discourse that subordinates girls and women.

But perhaps the most pervasive and visible counter-discourse that exists is the feminist movement (see CD5 in Figure 1). Feminism is broadly defined "as the struggle against male supremacy" (Thompson, 2001, 16). It is both a political movement and theoretical epistemology that centers on the goal of revealing the social construction of gender, and thereby the instability of it. Feminists challenge the taken-for-granted assumptions about the "naturalness" of gender roles, demonstrate how those gender roles have been constructed to privilege men, and offer alternatives to the currently accepted gender norms.

Conclusion

In this chapter, I have attempted to examine the issue of women's under-representation in mathematical careers using a post-structural feminist theoretical lens. I have argued that there are at least five competing dominant discourses that play a significant role in women's decision to enter mathematical careers. The first discourse, the mathematics discourse (see D1 in Figure 1) involves how mathematics as a field is talked about, what counts as mathematics, what it is used for, and who should do it. Currently, mathematics is talked about as an objective field that is highly competitive and individualized. Mathematics is taught in a highly regulated way that limits students' ability to understand the way "real" mathematics is conducted or how mathematics is related to the world around them. As a result, mathematics is exclusionary and alienating to a large portion of the population. The second discourse, the math ability discourse (see D2 in Figure 1), is directly related to the mathematics discourse, as who is considered mathematically able will be limited by what the nature of mathematics is considered to be. Decades of research on sex differences, coupled with media portrayals of men as more mathematically able than women, has resulted in a widespread belief that women are not good as good at mathematics. The third discourse, the math power discourse (see D3 in Figure 1), sends the message that to be powerful and successful in our society, one must be good at mathematics. Girls are encouraged to pursue mathematics careers so that they can succeed financially and have the same social power as men. The fourth discourse, the math deviance discourse (see D4 in Figure 1) exposes the widespread perception of mathematicians as socially deviant. The message is sent that it is “normal” to be bad at math, especially for women, and that if a person has strong mathematical ability, they were born with a rare math gene. Finally, the fifth discourse, the sexuality discourse (see D5 in Figure 1) involves all of the gendered messages that are sent to boys and girls about what it means to be a “real” man or woman.

While there are many other discourses that play a role in the lives of women, I have attempted to identify the ones that most directly influence women’s decisions to enter the field of mathematics. Specifically, I have attempted to create a dynamic model that can help explain how the five discourses interact and impact one another. In the past, theorists have examined some of these discourses independently, but to do so will only provide an incomplete understanding of the phenomenon and the variables involved. These five discourses are so interrelated and entangled that it would be insufficient to discuss them alone. Together, these discourses, in concert with the counter-discourses that are continuously emerging, create a complex web of messages about mathematics and gender that ultimately limit women’s views of what careers are available and acceptable for them to pursue. It is only through consciousness raising and the “clearing away” of dominant oppressive discourses that more girls and women will begin to see mathematics as a field where they belong and want to be a part of.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Women continue to be underrepresented in mathematics graduate schools and math-related careers (Kirkman, Maxwell, & Rose, 2004; NSF, 2007). This is problematic because women could potentially be missing out on high paying jobs, as the average salary of an individual with a master's degree working in a mathematics, science or engineering career was 17% higher than the average salary of those working in non-SES careers in 2003 (NSF, 2007). The lack of female mathematicians means that the field of mathematics cannot benefit from the diversity of thought that women could contribute, in addition to perpetuating the image of mathematics as a male domain.

Two reform movements in mathematics education that have been argued to improve girls' achievement and interest in mathematics are reform-based pedagogy and single-sex education. While the two reforms have not been systematically studied together, there is a great deal of research on both movements separately. This review of literature will begin by providing some historical background on the gender gap in mathematics, and summarize the currently available research on both reform movements. Next, the methodological problems with those areas of research, and gaps in the literature will be discussed. Finally, areas for future research will be presented, including a rationale for a study of single-sex math classes that employ reform-based pedagogy to examine the combination of the two reforms on girls' long-term career choices.

The Gender Gap: Past and Present

Historically, boys have outperformed girls on almost all measures of mathematical ability. For example, in 1978, 17-year-old boys scored an average of seven points higher than girls of the same age on the NAEP math test (NAEP, 2009). Sex differences in SAT scores were even more pronounced, with boys scoring an average of 43 points higher than girls in 1978 (CEEB, 2008). The cause of these sex differences in math achievement has been heavily researched and debated in the past several decades. Early research on sex differences in mathematical ability focused heavily on finding the biological differences between boys and girls. Those studies led the public to believe that there were structural differences between boys' and girls' brains that were responsible for boys' supposed superior mathematical ability. However, as the gender gap continues to close, those biological theories are discounted. For, even if girls and boys did start out with differing brain anatomies, almost parity of boys and girls performance seems to indicate that those differences are changeable with experience and that biology is not destiny.

Another theory that emerged during that time was the concept of differential course taking. Fennema (1974) was the first to attribute the discrepancies in mathematics achievement to sex differences in course enrollment. It was later found that "course enrollment statistically accounted for nearly all of the sex difference in mathematical performance at the end of secondary school" (Chipman, 2005, 15). In other words, once boys and girls start taking the same courses, the gender differences in math achievement begin to disappear.

This is evidenced by the closing gap in test scores on the mathematics portion of the SAT. In a report based on the SAT data of college bound seniors (CEEB, 2008), the gender gap in tests scores on the SAT mathematics test has decreased by 10 points from 1978 to 2008. While significant progress has been made in the past 30 years, boys still scored an average of 33 points higher than girls on the 2008 test, which demonstrates that there is still more work to be done (CEEB, 2008). Nonetheless, researchers argue that this persistent gender gap in SAT test scores and other similar entrance exams has little to do with an actual difference in mathematical ability (Chipman, 2005). Rather, it is believed that the gap is due to testing bias and the fact that test measures skills such as speed and guessing, which are not the same requisite skills for success in the mathematics classroom. In addition, Chipman (2005) explains that the SAT recently removed test items that favored girls, despite the fact that girls were already earning lower scores than boys. Similarly, she makes the claim that "because the existence of sex differences on the math SAT and similar tests is so well known, female examinees are always in the condition of "stereotype threat" when taking these tests (Chipman, 2005, 19).

An alternative explanation for the SAT gender gap involves the fact that overall, more girls take the SAT than boys. Thus, this group of girls is less "selective" which could result in the appearance of a gender gap (AAUW, 2008). Recently, all high school students in Illinois and Colorado have been required to take the ACT. In those states, boys no longer outperform girls on average, which provides support for the self-selection hypothesis (ACT Inc., 2005).

Another reason that researchers feel so strongly that entrance examinations must be biased is due to the fact that other national assessments seem to indicate that the gender gap in mathematical ability no longer exists. For example, research shows that girls are earning the same grades or higher in mathematics at all grade levels (Byrnes, 2005). Further, based on data from the Third International Mathematics and Science Study (TIMSS), which included 40 countries and three different age groups, Hanna (2003) found no significant gender differences in the achievement scores for third and fourth grade students or seventh and eighth grade students. As mentioned in Chapter 1, the National Assessments of Educational Progress (NAEP) for math, demonstrated that girls and boys earned nearly identical scores in grade twelve as well (Byrnes, 2005).

The gender disparity in mathematics course taking also appears to have been remedied. For example, on average, boys and girls took a similar number of mathematics courses during high school, 3.9 and 3.8, respectively (CEEB, 2008). When comparing the level of coursework, the same percentage of girls and boys are taking all types of mathematics courses through the first year of calculus (Huang, Taddese, & Walter, 2000). The only statistically significant difference in course taking was found in advanced placement calculus, where girls represented only 41% of those who took the higher-level Calculus BC exam in 2008 (CEEB, 2008). Catsambis (1994) conducted a similar study to determine if there were gender differences in learning opportunities, achievement, and choice of course taking. She discovered that overall, females are actually exposed to more learning opportunities in mathematics than males, as measured by enrollment in advanced courses.

Despite this narrowing of the achievement gap by gender, there are still significant differences in boys' and girls' enjoyment, interest and confidence in mathematics. Catsambis (1994) found female students tended to have less interest in mathematics and less confidence in their abilities, despite their overall higher achievement. She suggests that girls take math and sciences classes to meet college acceptance requirements, but that they may be "reluctant participants in mathematics learning" (212).   Similarly, Besecke & Reilly (2006) in their study of the key factors involved in students' career choices, found that "by 12th grade, males consistently have more positive attitudes than females about mathematics and science" (Besecke & Reilly, 2006, 11).

Significant gender differences in career aspirations of middle and high school students have also been found (Catsambis, 1994). In a survey of 2,213 seniors, Dick & Rallis (1991) found that among girls and boys who were taking both physics and calculus, the proportion of boys choosing a career in science or engineering was much greater than the proportion of girls doing the same. So, girls who are taking and excelling in courses that will supposedly allow them to enter high paying math and science careers are still not choosing those fields.   Therefore, "keeping open the door of opportunity to these careers does not guarantee that they will pass through it" (Dick & Rallis, 1991, 291). It seems clear that girls disinterest in and dislike of mathematics develops independently of students' learning opportunities and achievement levels. Therefore, many of the girls who are succeeding in the mathematics classroom are not happy to be there and very few see themselves entering a math or science career in the future.

> Perhaps we don't take seriously enough the voices that say again and again, 'but it doesn't make sense', and 'what's the point of it?' Perhaps what they are saying simply is true. Perhaps mathematics, doesn't make sense. Perhaps the fault is in the mathematics, and not the teaching, not the learning, not the people.   At the very least it is a question worth focusing on for a while (Johnston, 1995, pg 225, as quoted in Boaler, 1997).

In her three- year longitudinal case study of two schools, traditional Amber Hill and reform-based Phoenix Park, Boaler (1997) sought to understand girls' experiences in mathematics classrooms. The two schools differed greatly, one emphasizing speed and competition, and the other focusing on active inquiry, communication, and collaboration. It was obvious from both her observations and interviews that both boys and girls disliked the traditional approach at Amber Hill. However, "it soon became clear that the disaffection and under-achievement associated with this approach predominantly affected girls" (Boaler, 1997, 290). The primary reason for this difference, the author suggests, is because "many of the boys seemed willing to overlook the fact that they did not really understand what they were doing, whereas the girls remained acutely aware of the fact and were less willing to forgo or ignore their lack of understanding" (Boaler, 1997, 291).

These findings directly contradict previous research that suggests that girls lack of confidence in their own abilities is the reason they dislike mathematics (Tobias, 1993). Instead, Boaler (1997) argues that girls do not blame their lack of understanding on themselves, but on the fast-paced textbook oriented that is common in traditional mathematics classrooms. In this way, girls' aversion to mathematics can be viewed not due to a weakness or inadequacy, but instead as an intelligent response to the current way that mathematics is taught. Boaler suggests that girls' resistance to math is not because they think they aren't good at it, but because "they want to be able to understand mathematics and they won't accept a system which merely encourages rote learning of symbols and equations that mean little or nothing to them" (Boaler, 1997, 300).

Today, the gender gap in mathematics does not appear until graduate school and careers (Lynch, Leder, & Forgasz, 2001; NSF, 2007), but perceptions and attitudes about mathematics are thought to play a central role in the persistence of gender differences at those levels. According to a recent survey conducted by the National Science Foundation

(2007), while women earned 44.6% of bachelor's degrees, and 43.8% of master's degrees (see Figure 2) in mathematics in 2005, they only represented 27.1% of the mathematics doctorates awarded that same year (see Figure 3). In fact, when breaking those statistics down by United States citizenship, the numbers are even more startling, as U.S. women earn only 12.6% of all of the mathematics doctorates awarded. Unsurprisingly, men dramatically outnumber women as faculty in college and university mathematics departments, with only 13% of the total doctoral faculty in mathematics comprised of women in 2003 (Kirkman, Maxwell, & Rose, 2004). The situation is not much better in other math-related careers, as only 25.6% of all mathematical and computer science jobs were held by women in 2005 (NSF, 2007).

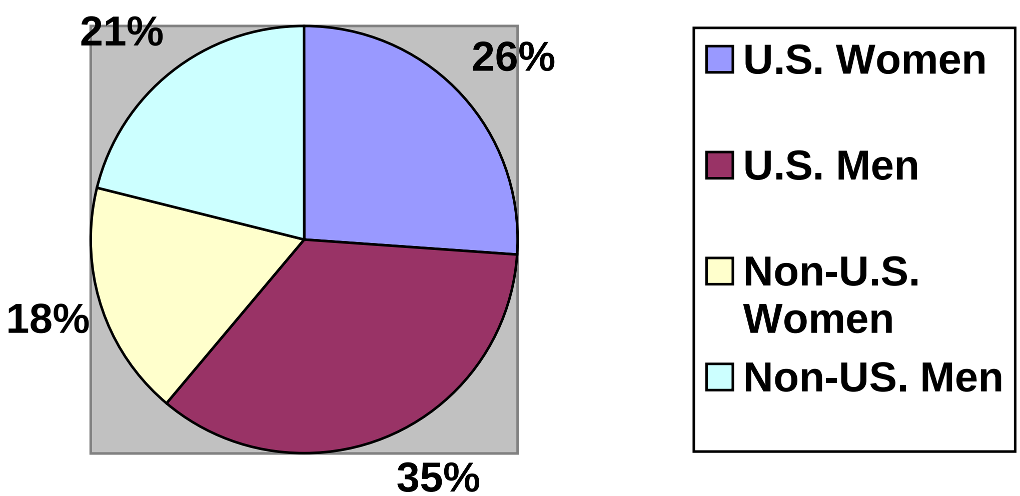


Figure 2. Masters Degrees in Mathematics Awarded by Gender and Citizenship (NSF, 2007)

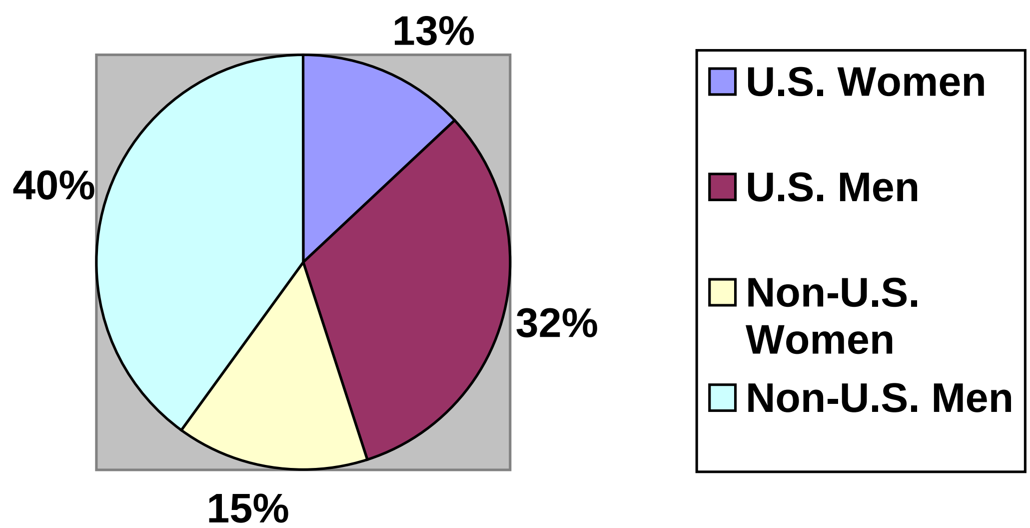


Figure 3. Doctoral Degrees in Mathematics Awarded by Gender and Citizenship (NSF, 2007)

This lack of women in graduate school mathematics and math-related careers is only a small portion of a larger problem. In fact, only about 0.5% of boys and girls plan to major in mathematics (NSF, 2007). That indicates that a very small percentage of the population, both male and female, is choosing mathematics as a viable career choice. Perhaps even more distressing, however, is the fact that mathematics has the highest undergraduate attrition rate of all liberal arts disciplines, with 60% of men and 72% of women leaving the major (Seymour & Hewitt, 1997). With such high attrition rates, it should be no surprise that degrees in mathematics account for only 1% of all bachelor's degrees earned each year (NSF, 2007).

The absence of women from mathematics, coupled with these other dismal statistics, have prompted researchers to look more closely at what is happening in college and university mathematics departments. Researchers have identified several challenges that women face at the collegiate level that may result in a rejection of mathematics as a field of study or potential career. First, women report feeling isolated in their male-dominated mathematics departments and describe how important a "critical mass" of women is to acquiring a sense of belonging (Lacampagne, et al., 2007). In addition, female graduate students have reported receiving less mentoring from male faculty than male students (Etzkowitz, Kemelgor, & Uzzi, 2000). This is often attributed to the fact that faculty are more likely to mentor same-sex students and while in 2003 approximately 30% of full-time graduate students were female, only 13% of the full-time faculty were female (Kirkman, Maxwell, & Priestly, 2004).

The lack of other women in the department is not the only reason women dislike the field of mathematics. Just as the high school girls discussed earlier complained about the irrelevance of what they were learning in mathematics, women in graduate school have similar grievances. In a study of seven women who left graduate programs in mathematics Stage & Maple (1996) discovered that women were frustrated by the lack of connection or application of the mathematics they were learning to the outside world. They also found the competitive and confrontational atmosphere and independent culture contradictory to the way they believed mathematics should be done (Stage & Maple, 1996).

Until recently, the gender equity problem in mathematics has focused on fixing the underachievement and non-participation of girls by changing the girls themselves, making them more confident and encouraging them to adopt more masculine traits (Boaler, 1997). The reasons for their lack of interest and confidence were assumed to be inherent to being female, and merely needed to be remedied. "The reasons for their actions are ignored and potential problems with mathematical epistemology, pedagogy and practice are not considered" (Boaler, 1997, 285). Instead, educators and researchers "unquestioningly assume that mathematics, and the way it is taught in schools, is appropriate for girls and that, if girls would only overcome their incorrect beliefs about and fear of mathematics and realize what harm is incurred by avoiding it, they too could be successful" (Lynch, Leder, & Forgasz, 2001, 188).

The role of women in the coming years will be to help expose the Eurocentric mathematics hegemony that has existed for far too long. In this way, "gender-oriented research in mathematics education challenges the meek acceptance of the male norm, identifying this norm as being culturally and historically determined, established at a time when women were excluded from mathematics education" (Lynch, Leder, & Forgasz, 2001, 189). Stanic (1989) suggests that the current mathematics curriculum is a "selective tradition" that in its present form, benefits those in power and reproduces social inequities. "This selective tradition results in school mathematics that is both mystified for those who are in the less privileged positions in our society and taken for granted by virtually everyone" (Stanic, 1989, 66).

In interviews with 48 high school students enrolled in AP calculus classes, Boaler & Greeno (2000) provide evidence that traditional mathematics teaching methods, which rely on memorization and the execution of predetermined steps, predominate in U.S. schools today, particularly at the higher levels. They argue that the ritualistic, procedural nature of school mathematics forces many students to reject it as a field of study because it runs "counter to their developing identification as responsible, thinking agents (Boaler & Greeno, 2000, 171). They argue that the more creative "connected knowers"

(Belenky, Clinchy, Goldberger, & Tarule, 1986), leave mathematics, leaving only those students who prefer "received knowing" to major in mathematics in college. However, when those "received knowers" enter upper level mathematics, they begin to realize that their received way of knowing is incongruent with the actual work of mathematicians. Thus, the "narrow mathematical practices within school are problematic, not only because they disenfranchise many students, but because they encourage forms of knowing and ways of working that are inconsistent with the discipline" (Boaler & Greeno, 2000, 191). Therefore, many "connected knowers" rejected mathematics prematurely because they disliked school mathematics, and many other "received knowers" rejected mathematics in college, when they discovered that it was incongruent with what they understood mathematics to be.

It is clear from both the research at the pK-12 level and higher education that the way that mathematics is taught needs to change. First, school mathematics needs to be made more aligned with the way mathematics is practiced. Second, mathematics as a discipline needs to be demystified, redefining it as "humane, responsive, negotiable and creative" so that it may become a more attractive field of study (Burton, 1995, 289).

Reform-Based Mathematics

Girls' and women's rejection of mathematics, coupled with the societal disinterest in the field has led to a call for a new way of teaching and learning mathematics at both the pK-12 and collegiate levels. One of the commonly suggested ways to accomplish this goal is reform-based or standards-based pedagogy. This type of curriculum is so called because of its alignment with the content and process standards created by the National

Council of Teachers of Mathematics (NCTM), which emphasize the use of problem-solving, reasoning, communicating mathematical ideas, and making connections between mathematical topics (NCTM, 2000).

> Compared to mathematics instruction commonly observed in American classrooms today, standards-based curriculum programs place less emphasis on memorization, on manipulating numbers (e.g., long division, factoring polynomials), and less time devoted exclusively to skills development (Goldsmith, Mark, & Kantrov, 1998; Schoenfeld, 1992) as quoted in (Riordan & Noyce, 2001).

Reform-based or standards-based curriculum is recommended as a method to improve students' mathematical ability, as well as their success in upper level mathematics because the pedagogy employed emphasizes requisite skills involved in the authentic problem-solving practices of mathematicians.

There is a great deal of research on the effects that reform-based mathematics has on students' achievement. In the study that was previously discussed that compared one traditional and one reform-based school, Boaler (1997) found that the reform-based school not only produced overall higher achievement, but also significantly decreased inequitable achievement scores by gender and class. At Amber Hill, 20% of boys and only 9% of girls earned a grade of A-C. Strikingly, at Phoenix Park, there were no significant gender differences in achievement. When looking at class differences, a similar trend appears. At Amber Hill, 80% of the high achievers were middle-class and 80% of low achievers were working-class, while at Phoenix Park, achievement was evenly distributed across classes (Boaler, 2002).

Riordan & Noyce (2001) found similar results in their study of traditional and reform-based curriculums. They collected data from all Massachusetts schools that had implemented either the Everyday Mathematics or Connected Mathematics curriculum in their schools. In all, 88 of these reform-based schools were included, along with a group of comparison schools. What they discovered was that across grade levels, schools using the standards-based programs as their primary mathematics curriculum performed significantly better than the students at traditional comparison schools. Their research also indicated that schools that had implemented the curricula for the longest period of time performed the best on the standardized tests. Perhaps most important, though, was the fact that the results were "remarkably consistent across students of different gender, race, and economic status" (Riordan & Noyce, 2001, 390). Other studies of these two curriculums have had similar positive findings for mathematics achievement (Carroll, 1997; Briars & Resnick, 1999; Lappan, Reys, Barnes, & Reys, 1998)

It should be noted that academic achievement is not the only positive outcome from reform-based instruction. In a study of nine introductory college-level physics courses, Fencl and Scheel (2006) investigated whether or not teaching methods affected the retention of students. He discovered that the attrition rates were significantly higher in the traditional classrooms than in the non-traditional classrooms. Overall, women desired to drop the course far more than men did, but the number of women who desired to drop the course was significantly less in the courses that included some type of collaborative, inquiry based instruction.

There is strong evidence to suggest that reform-based mathematics, when implemented long-term, has the potential to improve achievement and reduce gender, racial and socioeconomic inequities in mathematical ability. There is also substantial evidence that most students report greater enjoyment and interest in mathematics when taught using a reform-based pedagogy. Where the research is lacking, however, is in determining whether or not reform-based programs result in long-term changes in girls' attitudes about mathematics, or their beliefs about math as a male domain. There have also been very few studies that have investigated the relationship between reform-based pedagogies and entering mathematics careers. It seems reasonable to assume that if reform-based pedagogies increase short-term interest and enjoyment of mathematics, that it might also lead to long-term interest and the pursuit of math careers. More research is needed to explore this potential outcome.

Single-Sex Education

Introduction

Single-sex schools have also been championed as a means to improve girls' interest and achievement in mathematics. While the strength of reform-based pedagogy is that it can make mathematics more relevant and appealing to students, single-sex math classes have the ability to challenge gender stereotypes and assumptions about the masculinity of mathematics. One of the primary arguments for single-sex mathematics education is that boys tend to dominate coeducational mathematics classrooms, which creates an impression of mathematics as a male domain.

Gender inequities in coeducational classrooms across all grade levels have been well-documented. It seems that although girls and boys are in the same classes, they are not necessarily having the same experiences in those classes. For example, Lockheed and Harris (1984) in a study of 29 classrooms across two school districts, found that boys in all classes studied were more disruptive and received more teacher attention than their female peers. Sadker and Sadker (1984) found similar results in their three-year descriptive study of sex bias in classroom interactions, citing that boys participated much more often than girls, and received more praise, criticism, and remediation. In a follow-up study by the same authors, Sadker and Sadker (1994) explained how boys got called on more often by teachers, called out more than girls, and received more precise feedback from their teachers at all grade levels. Lee, Marks, and Byrd (1994) extended this work, finding that this gender inequity of teacher attention is even more pronounced in math, science, and technology classrooms. Single-sex schooling is offered as one way to eliminate this gender dominance. It is suggested that without males present, girls are more likely to become active participants in the classroom, get more attention from their teachers, take on more leadership roles, and finally, to view math as gender appropriate for girls.

Another reason it is argued that single-sex schools might be effective in changing the perception of mathematics as a male domain is due to the predominance of same-sex teachers in single-sex schools. Access to female math teachers and other female role models who are perceived as math experts has been found to be an important factor in both decreasing girls gendered perceptions of mathematics, and susceptibility to stereotype threat (Marx and Roman, 2002).

A common argument for why single-sex education is beneficial for both boys and girls is that it reduces the number of social distractions in the learning environment. In a two-year ethnographic study of 12 public single-sex academies, Hubbard and Datnow (2005) found this to be the case. Although the academies were disbanded after only three years due to financial constraints, the over 300 interviews conducted revealed that students and teachers acknowledge the benefits of a "diminished youth culture" (Riordan, 2008).

> When boys did not have girls present, they felt less need to showoff, act out, or engage in attention-getting behavior. Likewise, girls who did not have boys present did not have to vie for their attention. Instead of competing with each other, girls learned to work collaboratively, bond as friends, and become more focused on their academic work (Hubbard & Datnow, 2005, 121).

In addition to not having to worry about impressing the opposite sex, there were other less obvious benefits. Teachers acknowledged they had the time and space to give the "gender-specific real-life advice" that was so badly needed by the students in their district (Hubbard & Datnow, 2005, 126).

These benefits, along with the fact of boys' domination of coeducational classrooms provide a persuasive argument for single-sex learning opportunities for girls. However, in order to understand how those arguments fit into the greater political debate surrounding single-sex education, the history of the movement must be considered.

The History of Single-Sex Education in the United States

The issue of single-sex schooling has a long and controversial history. Until recently, research on this topic in the United States has been limited to private schools, with great emphasis placed on Catholic schools. This is due to the fact that for over 30 years in the U.S., under Title IX, single-sex education was illegal in any schools that received federal funding. The few public schools that did offer single-sex learning opportunities were often plagued by lawsuits and uncertainty. However, that all changed on October 25, 2006 when the U.S. Department of Education issued an amendment of the 1972 ruling, to allow the flexibility for schools to provide single-sex education (U.S. Department of Education, 2006).

During the 2008-2009 school year, 540 public schools in the U.S. offer some form of single-sex learning. Most are coeducational schools that offer single-sex classes, but 95 are completely single-sex (National Association for Single-Sex Public Education, 2009). This new generation of public single-sex learning environments provides a unique opportunity for educational researchers. Single-sex research has been criticized for its lack of comparison studies that control for pre-existing differences between school populations. The private and Catholic school research is frequently viewed as ungeneralizable to the public sector because of selection bias. Unsurprisingly, the results of single-sex studies have been inconsistent and conflicting within and between studies.

In general, supporters of coeducation believe that single-sex education does not reflect the society that we live in. They believe that separating students by sex will merely reinforce the gender differences between boys and girls, and that gender socialization will suffer. Or worse, a single-sex education movement could undo all of the work done to eliminate gender stereotypes. According to coeducation advocates, there is very little conclusive evidence that single-sex education benefits both boys and girls. However, even if there were evidence that suggests single-sex schooling is more beneficial, it is argued that we should learn from the single-sex successes and implement those positive practices in the coeducational environment.

Riordan (2008) challenges this rationale when he points out that currently the pressure is on single-sex schools to demonstrate that they are better than coeducational schools, not the other way around. In fact, when comparison studies are conducted, it is extremely rare for coeducational schools to perform better on any variable measured. He asserts that the shift to coeducational schools occurred as a result of financial constraints, not due to any educational theory or research outcome. In fact, coeducational schools have "never subjected to systematic research" (Riordan, 2008, 2). Thus, he argues that rather than placing the responsibility on single-sex schools to demonstrate their effectiveness, coeducational schools, which are currently the predominant school type in the United States, should have to prove that they are at least as effective and gender equitable as single-sex schools.

The Systematic Review

In 2005, the United States Department of Education underwent a systematic review of all of the research on single-sex education. Their goal was to "document the outcome evidence for or against the efficacy of single-sex education as an alternative form of school organization using an unbiased, transparent, and objective selection process" (U.S. Department of Education, 2005, ix). Using an approach adapted from the one used by the What Works Clearinghouse (WWC), they identified only 40 quantitative studies that satisfied the criteria. They also attempted to conduct a review of qualitative research, but only 4 qualitative studies satisfied the criteria for inclusion. When discussing the methodology that they used for the selection process, the authors state,

> Invariably, qualitative studies that do not collect empirical data about the schools or the variables that they are studying will not be in a position to control for possible preexisting differences when evaluating their results. Even if the authors state that the schools are in the same geographical area and appear to draw from the same populations, one cannot guarantee that there are not subtle differences between the parent bodies, the faculties, or other factors (U.S. Department of Education, 2005, 8).

Of course, an argument can also be made that the quantitative research done on this topic cannot guarantee or control for all confounding variables. In fact, I might argue that qualitative research, in this case, might be better equipped to control for such variances, since the researchers inevitably have deep familiarity with the schools under study, and would be more likely to be made aware of those subtle differences between schools that might impact results. Regardless of the problems inherent in any selection process where some research is included and others are left out, there is still valuable information to be gleaned from the review.

As shown in Table 1 below, there is a great deal of support for single-sex schools, and very little support for coeducational ones. In terms of concurrent academic accomplishments, most of were split between positive findings for SS schooling, no difference, or null findings. For long-term academic achievement, there were only two longitudinal studies that were included in the meta-analysis, which indicates a lack of this type of research. The results for concurrent adaptation and socioemotional development are much more difficult to summarize, as the range of outcomes included are very diverse. Those studies and their outcomes, split between support for single-sex schools and no differences, will be discussed later on in this review.

Table 1. Summary of Findings (U.S. Department of Education, 2005)

Outcome	*Total*	*Pro-SS*		*Pro-CE*		*Null*		*Mixed*	
	Number of Studies	Number of Studies	Percent	Number of Studies	Percent	Number of Studies	Percent	Number of Studies	Percent
Concurrent Academic Accomplishment									
1) All-Subject Achievement Test Scores	9	6	67%	1	11%	2	22%	0	0%
2) Mathematics Achievement Test Scores	14	3	22%	0	0%	8	56%	3	22%
3) Science Achievement Test Scores	8	2	25%	0	0%	5	62%	1	13%
4) Verbal/English Achievement Test Scores	10	3	30%	0	0%	7	70%	0	0%
5) Grades	1	0	0%	0	0%	1	100%	0	0%
6) Social Studies Achievement Test Scores	1	1	100%	0	0%	0	0%	0	0%
Subtotal	**43**	**15**	**35%**	**1**	**2%**	**23**	**53%**	**4**	**10%**
Long-Term Academic Accomplishment									
7) Postsecondary Test Scores	2	1	50%	0	0%	1	50%	0	0%
8) College Graduation	1	0	0%	0	0%	1	100%	0	0%
9) Graduate School Attendance	1	0	0%	0	0%	1	100%	0	0%
Subtotal	**4**	**1**	**25%**	**0**	**0%**	**3**	**75%**	**0**	**0%**
Concurrent Adaptation and Socioemotional Development									
10) Self-concept	7	4	57%	0	0%	3	43%	0	0%
11) Self-esteem	6	1	17%	2	33%	3	50%	0	0%
12) Locus of Control	5	3	60%	0	0%	2	40%	0	0%
13) School Track/Subject Preference	14	5	36%	2	14%	6	43%	1	7%
14) Educational Aspirations	3	2	67%	0	0%	1	33%	0	0%
15) Career Aspirations	2	2	100%	0	0%	0	0%	0	0%
16) Delinquency	4	2	50%	0	0%	2	50%	0	0%
17) Attitudes Toward School	5	1	20%	1	20%	1	20%	2	40%
18) Time Spent per Week on Homework	2	1	50%	0	0%	1	50%	0	0%
19) Attitudes Toward Working Women	1	1	100%	0	0%	0	0%	0	0%
Subtotal	**49**	**22**	**45%**	**5**	**10%**	**19**	**39%**	**3**	**6%**
Long-term Adaptation and Socioemotional Development									
20) School Completion	1	1	100%	0	0%	0	0%	0	0%
21) Postsecondary Success	1	0	0%	0	0%	1	100%	0	0%
22) Postsecondary Unemployment	2	1	50%	0	0%	1	50%	0	0%
23) Eating Disorders	1	0	0%	1	100%	0	0%	0	0%
24) Choice of College Major	1	1	100%	0	0%	0	0%	0	0%
25) Sex-Role Stereotyping	2	1	50%	1	50%	0	0%	0	0%
26) Political Involvement	1	1	100%	0	0%	0	0%	0	0%
27) Percent Married to First Spouse	1	0	0%	0	0%	1	100%	0	0%
Subtotal	**10**	**5**	**50%**	**2**	**20%**	**3**	**30%**	**0**	**0%**
Perceived School Culture									
28) Climate for Learning	1	1	100%	0	0%	0	0%	0	0%
29) Opportunities for Leadership Roles	2	1	50%	0	0%	1	50%	0	0%
30) School Environment	1	0	0%	0	0%	1	100%	0	0%
Subtotal	**4**	**2**	**50%**	**0**	**0%**	**2**	**50%**	**0**	**0%**
Subjective Satisfaction									
31) Satisfaction with School Environment	1	0	0%	1	100%	0	0%	0	0%
32) College Satisfaction	1	1	100%	0	0%	0	0%	0	0%
Subtotal	**2**	**1**	**50%**	**1**	**50%**	**0**	**0%**	**0**	**0%**
TOTALS	**112**	**46**		**9**		**50**		**7**	

From that extensive review, this statement was made:

> It is more common to come across studies that report no differences between SS and CE schooling than to find outcomes with support for the superiority of CE. In terms of outcomes that may be of most interest to the primary stakeholders (students and their parents), such as academic achievement test scores, self-concept, and long-term indicators of success, there is a degree of support for SS schooling (U.S. Department of Education, 2005, xvii).

Achievement

Academic achievement is, by far, one of the most important outcomes to stakeholders. Therefore, it should come as no surprise that it is the most heavily research area in single-sex education, as researchers attempt to use achievement tests to provide support for single-sex schools. In fact, of the 44 quantitative studies included in the U.S. Department of Education (2005) review, nearly 30 of them included some form of academic achievement as a measurement variable. Of the 9 studies included in the review that tested all-subject achievement test scores, 67% found that single-sex education was associated with higher scores, and only 11% showed higher scores for coeducational settings. A later review, also conducted by the U.S. Department of Education in 2008, found similar results with 35% of all studies showing that students from single-sex schools performed better, with only 2% of studies supporting coeducational schools (U.S. Department of Education, 2008, xi).

Due to the lack of single-sex public schools in the United States, much of the early research on this subject was conducted in Catholic schools, as they more closely resembled public school student populations than other independent schools. There is a great deal of evidence from this line of research to support the idea that girls who attend single-sex schools have higher academic achievement than their female peers at coeducational schools. Both Carpenter & Hayden (1987) and Caspi (1995), when comparing girls at coeducational and single-sex Catholic schools, found that the single-sex girls' achievement schools were higher. In a similar study comparing 690 black and Hispanic students from single-sex and coeducational Catholic schools, Riordan (1994) found that students from the single-sex schools scored significantly higher on cognitive tests, even after controlling for home background and initial cognitive ability.

In perhaps one of the largest Catholic school studies conducted on this subject, Lee & Bryk (1986), using data from the national *High School and Beyond* survey, compared 1,807 students in 75 single-sex and coeducational Catholic schools. They found that the students at single-sex schools had higher academic achievement than students at coeducational schools, with a greater effect for girls. The authors argue that such a large effect size (.20), represents the equivalent of a full year of extra learning gained by single-sex students.

However, the findings from that study are not without controversy. When Marsh (1989) repeated the study using the same data, this time controlling for background differences in the populations, no significant differences were found between school types. The few differences that did exist did not consistently favor students from single-sex or co-ed schools. In fact, another more recent study by LePore & Warren (1997) of Catholic schools using longitudinal data from 1988 to 1994 had similar results. There were no significant differences between school types, and any differences that were found were due to pre-enrollment differences.

In addition to the Catholic school studies, findings from international studies have also been used to provide support for single-sex school. In some cases, we must be extremely careful about making generalizations from international studies for several reasons. First, some countries have a long history of public single-sex education, and those schools were often started for very different ideological reasons than the ones being opened in the United States today. Second, in some countries, single-sex schools are only being offered to a select group of girls, rather than to the entire female population.

Thus, any findings from those studies will inherently be biased without appropriate statistical controls.

Despite their obvious limitations, international studies can still make contributions to the single-sex education debate, and often provide compelling evidence to support single-sex schools. For example, in a New Zealand study of single-sex and coeducational high school students, Woodward, Fergusson, & Horwood (1999) found significant differences in academic achievement of both boys and girls, with students from single-sex schools performing better. In another study examining the performance gains of students at single-sex and coeducational schools in England, Spielhofer, O'Donnell, Benton, Schagen, & Schagen (2002) found that girls who attended single-sex schools attained much higher performance gains than girls who attended coeducational schools. Further, they discovered that girls with lower prior all-subject achievement who attended single-sex schools made the greatest performance gains.

As mentioned previously, research on public single-sex schools in the United States is much more limited, although the recent creation of new public single-sex schools is providing new research opportunities. In an effort to measure the success of these new public single-sex schools that are being developed across the country, the U.S. Department of Education (2008) engaged in a descriptive study of 19 of the 20 single-sex schools that were in operation as of fall 2003. Interestingly, 17 of the 19 schools studied were predominantly nonwhite, and 18 of the schools received free or reduced lunch services. The study included a survey of public single-sex schools, along with an exploratory observational study of a sample of the single-sex public schools. In regard to academic achievement, what the researchers found from their observations was that at all grade levels, single-sex students were more likely to complete their homework and were more likely to be engaged in academic activities than their peers at coeducational schools.

One of the public elementary schools included in the U.S. Department of Education (2008) study was the Brighter Choice Charter School (BCCS). The 3-year study of the Connecticut school utilized the same measurements and procedures as the ones used in a large national study called the Early Childhood Longitudinal Study Kindergarten Cohort (Riordan, 2008). In the first two years of the school's existence, there were no differences between the BCCS students and the matched students in the national sample, all of which scored well below the national average. However, by the end of grade three, the BCCS students, whom are predominantly low-income black and Latino students, were scoring *above* the national average in both mathematics and reading. While further research needs to be conducted to substantiate these findings, they seem to suggest that public single-sex schools can have a moderate impact on students' overall academic achievement.

Self-Concept, Self-Esteem, and Locus of Control

Beyond academic achievement, improved self-confidence is often a common rationale for single-sex schools, particularly for girls. For, it is has been found that girls tend to score lower on measures of self-confidence and self-concept than their male peers (AAUW, 1991). According to Fennema and Sherman (1978) girls' drop in self-confidence in their mathematical ability occurs before a decline in performance. In other words, their self-confidence is dropping independently of their academic achievement. Several different measures of self-confidence are typically discussed interchangeably, including self-concept, self-esteem, and locus of control. I will address each one separately below.

Self-Concept

Of the studies that tested self-concept that were included in the U.S. Department of Education (2005) review, 57% found that single-sex education resulted in greater self-concept, while the other 43% showed null findings. Based on these findings, it appears that single-sex education could potentially improve both academic achievement, and self-concept, among other things. For example, Riordan (1990), in his study of 902 students attending Catholic single-sex and coeducational high schools, found no differences in self-concept by school type, except when in the case of white females who attended single-schools. Those students were found to have higher self-concepts than white students attending coeducational schools. Similarly, Ciprani-Sklar (1996), when comparing public to Catholic schools, found no differences in general self-concept for females. However, she did find significant differences in mathematics and science self-concept for females, with girls attending single-sex schools reporting higher mathematics and science self-concepts than their coeducational counterparts.

Self-Esteem

The results for self-esteem are less conclusive. Riordan (1994), in his study of black and Hispanic Catholic high school students, found that boys who attended coeducational schools actually had higher self-esteem than boys who attended single-sex schools. He found no differences between the self-esteem of girls from single-sex and coeducational schools. Brutsaert and Bracke (1994) had similar findings when comparing single-sex versus coeducational schools in 60 private Belgian elementary schools. They found significant differences in self-esteem for boys where single-sex boys reported higher self-esteem than coeducational boys. They, too, found no differences in self-esteem for girls by school type.

International studies offer stronger support for differences in self-esteem, including two studies conducted in Northern Ireland (Granleese & Joseph, 1993; Cairns, 1990). Granleese & Joseph (1993) found that while girls' self-worth is similar at both single-sex and coeducational schools, the determinants of their self-worth varied greatly. While girls at single-sex schools relied on their behavioral conduct to determine their self-worth, girls at coeducational schools used physical appearance to measure their self-worth. Cairns (1990), instead of using one measure of self-esteem, decided to measure four different types, including social, cognitive, athletic, and general. What they discovered was that single-sex students had higher cognitive self-esteem than their coeducational peers, and interestingly, also reported a greater locus of control.

Locus of Control

Riordan (2008), among others, believes that self-esteem is not a reliable outcome measure. Instead, he recommends measuring locus of control, which "directly indicates the extent to which an individual feels that the social environment either facilitates or hinders the undertaking and completion of the tasks and goals" (21). He argues that students can have high self-esteem, as is the case with many Latino girls, and still have low environmental control. This, he thinks, could be the reason why the assumed correlation between self-esteem and achievement has not been proven.

Riordan (1990), in his earlier comparison study of single-sex and coeducational Catholic high schools, found that white females in single-sex schools reported higher locus of control that white girls in coeducational schools. In addition, he found that at-risk boys attending single-sex schools had significantly higher scores on locus of control than at-risk boys at coeducational schools. In his later study of black and Hispanic Catholic students, Riordan (1994) had similar findings, with both single-sex boys and girls reporting higher measures of environmental control than their coeducational peers.

In other words, there seems to be at least moderate support that students who attend single-sex are more likely to report that their environment helps or encourages them than students at coeducational schools. As a result, they feel like they have a greater sense of control over their environment, and their futures.

Other Outcomes

While improvements in academic achievement and self-confidence are the two most common arguments for why single-sex schools are beneficial, researchers have documented several other positive outcomes that should be mentioned. First, students in single-sex schools, when compared to students in coeducational schools, have been shown to have less delinquency (Caspi, 1995; Caspi, Lynam, Moffitt & Silva, 1993), lower dropout rates (Woodward, et. al, 1999), and more positive attitudes towards school (Lee & Bryk, 1986). Other studies (Lee & Bryk, 1986; Riordan, 1990; Riordan 2008) have found that students spend significantly more time on homework and more time on task in school. Finally, in a study of 5^{th} grade inner city boys, Singh, Vaught, & Mitchell (1998) found a correlation between single-sex classes and improved attendance. The boys in the coeducational classrooms missed an average of 9.24 days of school, while the boys in the single-sex classes only missed an average of 5.73 days (Singh, Vaught, & Mitchell, 1998).

Gender Equity

As discussed previously, one of the most compelling arguments for single-sex education is boys' domination of coeducational classrooms and the sexism continues to limit girls' equitable access to education. Therefore, when considering the effectiveness of single-sex education, it seems important to examine whether or not gender equity is accomplished in those schools.

As part of the National Study of Gender Group in Independent Secondary Schools, Lee, Marks & Byrd (1994) collected data from 21 U.S. independent schools, to see how prevalent sexism was, and who initiated it. In their observations of history, English, calculus, and chemistry classes, they found that sexism most common in all-boys schools. Even with a female observer, and allowing the schools to choose which classrooms were to be observed, sexism was present in every all-boys classroom that was taught by a male teacher. Therefore, these incidents of sexism were probably typical, and if anything, occur more frequently than was observed in this study. The researchers postulated that "the increased comfort level of same-gender relationships seemed to magnify these gendered messages and to render them acceptable"(pg 106). Girls' schools showed a more subtle form of sexism, which involved academic dependence and non-rigorous instruction. This study suggests that sexism takes place in both single-sex and coeducational classrooms, and that sexism might be even more reinforced in single-sex environments.

On the other hand, several other research studies support the claim that single-sex classes are more gender equitable. Two studies (Streitmatter 1998, Gillibrand, Robinson, Brown & Osborn, 1999) of high school physics classes both found that girls were under-enrolled in physics, and that boys dominated in the mixed-sex classes. Girls complained that they felt inferior to boys, and that the boys controlled lab time, putting girls in secondary roles. Gillibrand et al. (1999) discovered that the girls in the single-sex class were associated with increased confidence levels, and choosing upper level physics the following year. While the girls expressed a preference for working in a coeducational setting, they all said they would choose single-sex classes again for physics if they had the choice. The girls claimed that they learned better in the single-sex physics classes because they were more cooperative, non-competitive, and were given more opportunities for active participation. A similar Belgian study found that single-sex education is correlated with lower stress levels for girls and a greater sense of belonging (Brutsaert & Van Houtte, 2004).

The current research on this topic is inconclusive. More research is needed to determine if single-sex classes are more gender equitable than coeducational ones, and the effectiveness of non-sexist professional development training for teachers needs to be explored.

Perceptions and Attitudes about Mathematics

As discussed earlier in this review, studies have shown that as girls progress through their schooling, they report liking math less and feeling less confident in their mathematics ability (Catsambis, 1994; Besecke & Reilly, 2006). Research on girls' attitudes towards math and science provide strong evidence that the single-sex environment can have a positive effect on girls (Haag, 1998). For example, Lee and Bryk (1986) found that U.S. girls attending single-sex schools had significantly higher interest in math and were more likely to enroll in the subject than girls at coeducational schools. Several other studies conducted in the U.S., England and Nigeria had similar findings, with girls from single-sex schools having more positive attitudes about math than girls from coeducational schools (Gwizdala & Steinback, 1990; Spielhofer, O'Donnell, Benton, Schagen, & Schagen, 2002; Stables, 1990; Mallam, 1993). Finally, Lee and Lockheed (1990), when comparing single-sex and coeducational schools in Nigeria, found significant differences in the stereotypic views of mathematics with single-sex girls exhibiting far less stereotypic views of the subject than coeducational girls.

Overall, these findings suggest that single-sex schools could increase girls' interest in mathematics, as well as decrease their stereotypic perceptions of math as a male domain. While these studies are not free from their methodological issues, they offer compelling evidence that single-sex education could play a role in improving girls' representation in the field of mathematics.

Career Choice

Of course, increasing girls' interest in mathematics in high school does not necessarily mean that they will enter mathematics careers later on. Unfortunately, there is a significant lack of research on the correlation between single-sex schools and career choices. Most studies that explore single-sex girls' career interests rely on self-reports at the end of high school, or follow students through their choice of college major. However, those statistics are problematic, as it is known that mathematics has an extremely high attrition rate, which means that many girls (72%) who initially select math as a major switch majors before graduation (Seymour & Hewitt, 1997). Further, those studies have not followed single-sex girls through graduate school or the beginning of their careers.

Nonetheless, the research that does exist suggests that single-sex schools can improve girls' career aspirations in general, and in math-related careers specifically. In a study of 845 high school girls, Watson, Quatman, and Edler (2002) discovered that girls from single-sex schools had higher ideal and realistic career aspirations than girls from coeducational schools and did not demonstrate a drop in ideal or realistic career aspirations as was demonstrated in the coeducational girls. In a study of a 4-week summer program for inner-city minority girls, Campbell (1995) found that students who attended the program increased the number of math courses they were planning to take by 45%. In a follow-up study of those same students 2.5 years later, it was found that 90% of them were planning to take calculus. Thompson (2003) compared private coeducational and catholic single-sex girls and found that girls from the single-sex schools were 1.7 times more likely to choose a "gender-mixed" major as opposed to a “feminine” one. In a study of 60 female college students, Rubenfeld & Gilroy (1991) had similar results, finding that women who had attended single-sex high schools (and had brothers) were more likely to show an interest in male-dominated occupations than women who had attended coeducational schools. Again, these studies relied solely on the expressed interests of the girls and women, and did not actually follow the participants to see if those career interests were acted upon long-term.

Despite the lack of longitudinal studies to investigate the long-term effects of single-sex schooling on career choices, research on all women’s colleges suggest that they can be extremely effective. For, even though students attending women’s colleges “make up only 4.5% of all female college students, they account for one fourth to one third of all female board members of Fortune 1000 companies and half the women in Congress” (Mael, 1998, 102). Clearly, more systematic longitudinal research is needed to determine if single-sex programs result in more women entering mathematics or other male-dominated fields.

Methodological Issues

Opponents of single-sex education argue that incorporating single-sex schooling without conclusive evidence to support it is irresponsible. While much of the existing research does support single-sex education for girls, it is impossible to tell if the positive results were due to selection bias. For, even if comparison groups are matched demographically, it is possible that a different type of student will elect to attend a single-sex school. In addition, much of the research has been conducted in private and Catholic schools, which further compromises the ability to generalize the results of those studies.

However, selection bias is not the only methodological issue in this field of research. Other critics of single-sex education assert that any significant differences found are really due to organizational differences, smaller class sizes, student-teacher relationships, and school leadership, rather than school type (Hubbard & Datnow, 2005). Riordan (2008) addresses this problem directly when he argues that there is a methodological problem with looking at single-sex education and coeducation as a dichotomy because "it overlooks the likely possibility that an effective school is one that combines two or more (probably more) factors" (10). Further, it is argued that it is not effective to conduct studies that try to prove that single-sex schools are better or worse overall than coeducational schools. Instead, researchers should conduct smaller studies that narrow in on one aspect of single-sex schooling and attempt to prove if it is beneficial (U.S. Department of Education, 2005).

The research on the impact of single-sex schooling on academic achievement is mixed. However, Riordan (2008) suggests that one of the reasons for such diversity of results has a great deal to do with how strongly the school has embraced the concept of single-sex education. He argues that the most successful single-sex schools are the ones that have a "firm embracement of the single-sex approach", and a "commitment to identifying and refining teaching strategies that do not emphasize gender specific pedagogy" (Riordan, 2008, 33-34). Haag (1998) furthers this point when she says, "the structure of single-sex education, in other words, does not in and of itself ensure any particular outcomes, positive or negative, because it has multiple inspirations and forms" (14). In other words, some single-sex schools will be very successful and others will not, depending upon how the model is enacted.

This issue of degree of embracement directly affects the findings from reform-based mathematics studies as well. Depending upon a school's commitment to a particular reform-based curriculum, and the teachers' teaching of it, results can vary dramatically. Just because two schools, or even two teachers use the same curriculum does not necessarily mean they are teaching the same mathematical content or processes. Therefore, for studies investigating the impact of single-sex reform-based mathematics programs on girls' career interests, researchers will need to find a way to ensure that both reforms have been firmly embraced and enacted in qualitatively similar ways across schools to determine their effectiveness.

In addition, the fact that both public single-sex schools and reform-based mathematics are being newly implemented means that the cumulative effects of such programs may not be apparent immediately. Salomone (2006) asserts that single-sex education is in an "embryonic" stage, and that those programs need time to become established before truly evaluating them. Riordan (2008), too, suggests that the relatively small effects that are being found in short-term studies of new single-sex public schools could result in much larger cumulative effects in the long-term. For example, if a study of single-sex math classes shows that girls demonstrated a 2-month gain in their math achievement, that could result in a gain of over a year's worth of learning by the time those students graduated from high school. This issue of long-term implementation directly applies to research on reform-based mathematics pedagogy as well. Several studies (Carroll, 1997; Briars & Resnick, 1999) have found that the longer the curriculum is implemented, the more positive the results can be, as students have time to adjust to the new type of learning and teachers can become fully trained and practiced in the new pedagogy.

Finally, as Mael (1998) points out, academic achievement is often seen as the most important criterion on which to base single-sex school (and reform-based mathematics) effectiveness. As a result, much of the current body of research has relied heavily on quantitative research methodologies using standardized test scores. However, if less traditional measures of success were used (i.e. pregnancy or dropout rates, career choices), the evidence in support of single-sex schools may very well be more significant.

Gaps in the Literature

As is evidenced by this review of literature, the research on single-sex education and reform-based mathematics is paradoxically both extensive and deficient. To begin, there is a surprising lack of studies that explore the relationship between either single-sex education or reform-based mathematics and career interests. Very few studies have included careers as an outcome, and even fewer of them have actually followed-up with participants to see if they entered those careers. This is clearly an area where further research is necessary. Related to this issue, the overwhelming majority of studies discussed in this review were short-term quantitative studies, often relying on test scores or self-report surveys from which to generate conclusions. While short-term studies can be extremely illuminative, more longitudinal studies are necessary to determine if students' self-reports translate into long-term results. Also, just proving that one school type has better outcomes than another does not explain why that type of school is so effective. If, indeed, single-sex schools or reform-based mathematics are proven to be successful, more qualitative research will be necessary to determine what it is that those programs are doing differently to achieve those results. This is particularly important when considering that it is extremely difficult to control for selection bias. Therefore, it is imperative that the contexts of those settings be fully described so that stakeholders may decide for themselves whether or not such a reform will have similar results for their population of students.

In addition to incorporating more qualitative research methods, there is a need for more research that employs a feminist standpoint epistemology. For too long, research about girls and mathematics has objectified and categorized girls in comparison to their male peers. Very few researchers have explored the issue from the girls' perspective, hearing their own voices, and learning about their lived experiences in the mathematics classroom. Such research will not only inform the discussion surrounding girls and mathematics, but it will also provide a unique perspective from which to critique the taken-for-granted assumptions about the nature of mathematics in an effort to make it more accessible and appealing for all students (Damarin, 1995).

Conclusion

With the current evidence supporting both reform-based mathematics and single-sex education, it seems logical that purposefully combining the two reforms would have an even larger effect. It is believed that one of the reasons some of the research on single-sex schools for math-related outcomes has been so inconclusive is because the girls are taught in a variety of ways, using a variety of curricula. Currently, there is a lack of research on single-sex schools that compares or controls for the type of mathematics pedagogy being employed. Further, there is little research on the long-term effects of either type of reform on career choice. It is for this reason that a longitudinal qualitative study of single-sex reform-based mathematics programs is necessary to determine the long-term effects of such programs on career decisions. It is essential that we learn from contexts where minority girls are succeeding and enjoying mathematics, and use those contexts as a guide for providing more equitable and enjoyable mathematics learning experiences for all students (Stanic, 1989).

CHAPTER 3

METHODS

Introduction

This chapter will be a discussion of a study designed to address the gaps in the literature identified in the review of literature and to operationalize the theoretical concepts discussed in Chapter 1. The chapter is organized as follows: 1) purpose of the study, 2) research questions, 3) research context, 4) data collection methods, 5) reliability and validity, 6) researcher subjectivity, 7) research ethics, and 8) data analysis procedures.

Purpose of the Study

The purpose of this study is to determine the long-term impact of a single-sex reform-based summer math program on high school girls. In particular, it will explore the types of discourses that are being produced and reproduced in the program, as well as the long-term impact those and other discourses have on women's career decisions and experiences upon entering mathematical careers.

Research Question

This study addressed the following research question:

What is the long-term impact of a single-sex reform-based summer math program on high school girls?

Sub-Questions:

1. Which discourses are being produced or reproduced in a single-sex reform-based mathematics summer program?

2. How did the program influence the girls' career decisions? Which discourses played the biggest role in those decisions?

3. How did the program influence the girls' perceptions of the nature of mathematical work and the field of mathematics?

4. How did the program influence the girls' beliefs about their own mathematical ability and the math ability of girls and women in general?

5. How did the program influence the girls' interpretation of their gendered role as women in society? What do they see as attainable for themselves?

6. How did the program influence the girls' ideas about the importance of mathematics in society? Do they see math ability as powerful?

7. How did the program influence the girls' beliefs about whether being mathematically able is deviant or normal? As women, are there social benefits for being mathematically able?

8. Did consciousness-raising occur? If so, do the girls transfer those counter-discourses to new settings? Do those experiences give them skills to be critical of dominant discourses in other parts of their lives? How does exposure to those discourses affect their experience in the math field? Do they act as change agents within the field, or do they reproduce the dominant discourses?

Researching a successful single-sex SummerMath program provided valuable information about how to effectively implement reform-based mathematics curricula, provide opportunities for consciousness-raising, and teach mathematics in an inclusive, and equitable way. This study not only explored the lived experiences of girls in single-sex mathematics programs, but also contributed to a more dynamic model that can begin to explain how competing discourses influence the girls' decision to enter mathematics careers. In addition, this study explored strategies that can be used to disrupt the dominant discourses that reproduce inequities in mathematics education, and that may lead to long-term change in the way that mathematics is taught and practiced.

Research Methods

Introduction

Using a mixed-method research design, this study included the collection and analysis of both quantitative and qualitative data. According to Creswell & Plano Clark (2007), the central premise of a mixed-method approach "is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone"(5). There are several benefits to a mixed-method research design, primarily due to the fact that "the combination of both approaches can offset the weaknesses of either approach used by itself" (Creswell & Plano Clark, 2007, 9). For example, some of the weaknesses of quantitative research are that it does not allow an examination of the context of the research, does not allow the voices of participants to be heard directly, and quantitative researchers' personal biases are not examined (Creswell & Plano Clark, 2007). In contrast, one of the strengths of qualitative research is that it often involves prolonged fieldwork in a naturalistic setting (Merriam, 1998). This not only allows the researcher to consider the context when collecting data, but also provides multiple opportunities for forming relationships with participants. This intensive data collection process allows researchers to see the phenomenon from an insider's or "emic" perspective (Merriam, 1998, 6).

On the other hand, qualitative research is not without its weaknesses, and including quantitative data in a research design can help to counteract those deficiencies. For example, qualitative research is often criticized because of biases that can arise from using researchers as the "primary instrument of data collection and analysis" (Merriam, 1998, 7). Similarly, it is criticized for its lack of generalizability due to small sample sizes and inability to replicate research methods (Creswell & Plano Clark, 2007). The use of quantitative methods in conjunction with qualitative ones can result in a stronger triangulation of data, a deeper understanding of the phenomenon being studied, and a minimizing of limitations to the study.

According to Merriam (1998), “qualitative researchers are interested in understanding the meaning people have constructed, that is, how they make sense of their world and the experiences they have in their world” (6). I am interested in the lived experiences of women in mathematics, and particularly, their lived experience in a summer mathematics program for girls. As mentioned in Chapter 1, I utilized a feminist standpoint theory (Damarin, 1995), which privileges the voices and experiences of women in mathematics precisely because they have been marginalized within the field of mathematics. Their unique perspective and experiences provided a different reading of mathematics. Such an “emic” perspective cannot be gleaned simply from a survey or experimental study. Instead, I needed to spend a great deal of time with my participants, gathering both qualitative and quantitative data, to gain a deep understanding of their experiences.

For this study, I incorporated field observations of the current SummerMath program, pre- and post- program surveys of former SummerMath program participants, phenomenological interviews with former SummerMath program participants, and artifact collection from the SummerMath site. Field observations, artifact collection, and survey data collection occurred in July 2009. Interviews were conducted between August 2009 and January 2010. Please refer to Table 2 for the complete data collection matrix, and Table 3 for examples of the operationalized theoretical concepts that guided this study.

Table 2. Data Collection Matrix

What do I need to know?	*What theoretical concept is being explored?*	*Why do I need to know this?*	*What types of data will answer this question?*	*Who will provide this information?*	*When will this data be collected?*
1. Which discourses are being produced or reproduced in a single-sex reform-based mathematics summer program?					
a. What are the girls' lived experiences in the SummerMath program?	all	In order to understand how their experiences in the program affected their career decisions, I have to understand what those experiences were	field obs, interviews, surveys	current students former students	July 2009 (obs) Aug-Nov2009 (interviews)
b. What do the women say about what made the SummerMath program unique?	all	What the women choose to say about what made it unique will indicate which aspects of the program were the most significant	interviews	former students	Aug-Nov2009 (interviews)
2. How did the program influence the girls' career decisions? Which discourses played the biggest role in those decisions?					
a. What do participants see as the biggest influences on their decision to enter or not enter a mathematical career?	all	I will need to understand how the participants make sense of their decision to enter or not enter mathematical careers, and the stories they tell about that process	interviews	former students	Aug-Nov2009 (interviews)
b. What were the women's mathematical experiences after the SummerMath program like?	all	In order to determine which discourses are most salient in the women's career decisions, I need to understand what happened to them after leaving the program	interviews	former students	Aug-Nov2009 (interviews)
c. Are there any other ways that the SummerMath program impacted the participants?	all	This will hopefully identify some unexpected consequences of participation in the program	surveys, interviews	former students	Aug-Nov2009 (interviews)
3. How did the program influence the girls' perceptions of the nature of mathematical work and the field of mathematics?					
a. What were the girls' perceptions about the nature of mathematics prior to entering the program?	math discourse	Participants' perceptions prior to entering the program will impact how they experience it and their perception of it	surveys, interviews	former students	Aug-Nov2009 (interviews)
b. How did those perceptions change as a result of participating in the program?	math discourse	Provide insight into the short- and long-term impact that the program had on the participants' perceptions	surveys, interviews	former students	Aug-Nov2009 (interviews)
c. How were the girls' experiences in the program different than their mathematical experiences in their high schools or in college/career?	math discourse	In order to understand the types of mathematical discourses they brought into the program, I need to understand what their prior experiences in mathematics were like	interviews	former students	Aug-Nov2009 (interviews)
d. Which discourses are present that challenge or reproduce the dominant discourses and practices of the field of mathematics?	math discourse	In order to determine whether dominant discourses are being reproduced or challenged, I need to systematically record which discourses are present at the site	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
e. What was the long-term impact of the program on the girls' perceptions of the nature of mathematics?	math discourse	To determine the long-term impact of the program, I will need to find out if the changes in perceptions about the nature of mathematics persist over time, even after re-entering a traditional math setting	interviews	former students	Aug-Nov2009 (interviews)
4. How did the program influence the girls' beliefs about their own mathematical ability and the math ability of girls and women in general?					
a. What were the girls' beliefs about their own mathematics ability and the math ability of girls in general prior to entering the program?	math ability discourse	In order to understand how their perceptions about math ability changed, I need to know what beliefs about math ability they brought to the program and how those beliefs impact their perception of their own mathematical ability	surveys, interviews	former students	Aug-Nov2009 (interviews)
b. How did those beliefs change from participating in the program?	math ability discourse	If their beliefs change, it can be inferred that a counter math ability discourse may exist	surveys, interviews	former students	Aug-Nov2009 (interviews)

c. What programmatic or pedagogical structures influenced those changes in beliefs?	math ability discourse	Will need to know if the changes in beliefs about ability are due to the way math was taught, the single-sex environment, or the way math ability was discussed—do they believe more in their ability because they had more support, or do they really see "ability" differently?	surveys, interviews	former students	Aug-Nov2009 (interviews)
d. Which discourses are present that challenge or reproduce the dominant discourse about girls' math ability?	math ability discourse	Cannot determine if the program is challenging or reproducing dominant discourses without first recording which discourses are present.	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
e. What was the long-term impact of the program on the girls' beliefs about their math ability?	math ability discourse	To determine if there is a long-term impact, I will need to determine if the changes in beliefs persist over time	interviews	former students	Aug-Nov2009 (interviews)
5. How did the program influence the girls' interpretation of their gendered role as women in society?					
a. What other single-sex experiences have the women had? Did the participants find the single-sex environment helpful in any way? If so, how?	sexuality discourse	Need examine what role the single-sex environment played in their experiences	interviews	former students	Aug-Nov2009 (interviews)
b. Did the program reinforce or challenge gender role stereotypes and the dominant sexuality discourse?	sexuality discourse	Need to know how being female is discussed in the program	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
c. In what ways did the program make the girls aware of gender inequities in mathematics, in their school, or in society?	sexuality discourse, consciousness-raising	This will help determine if the program explicitly or implicitly discuss women's role in mathematics?	interviews	former students	Aug-Nov2009 (interviews)
d. What do the women see as attainable for themselves? What choices do they have?	sexuality discourse	What they see as attainable will illustrate what types of gender discourse they have internalized	surveys, interviews	former students	Aug-Nov2009 (interviews)
6. How did the program influence the girls' ideas about the importance of mathematics in society?					
a. Do they think that mathematics should be so valued?	math power discourse	Girls in the program are being encouraged to pursue mathematics careers, but it is unclear whether they are ever asked to examine why math is so valued	interviews	former students	Aug-Nov2009 (interviews)
b. Do they value it? If they don't value mathematics, why don't they?	math power discourse	If participants don't value mathematics their reasons for not valuing it will provide information about the mathematics discourse itself and how that intersects with the math ability and sexuality discourses	interviews	former students	Aug-Nov2009 (interviews)
c. Do they feel they have more social power because they can do mathematics?	math power discourse	Will establish if the participants see math as socially powerful or beneficial	interviews	former students	Aug-Nov2009 (interviews)
d. Which discourses are present that challenge or reproduce the dominant discourse about math as power?	math power discourse	Will determine if the program is reinforcing the math power discourse	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
7. How did the program influence the girls' beliefs about whether being mathematically able is deviant or normal?					
a. Do the women see themselves as mathematically able?	math deviance discourse, math ability discourse	How they identify can provide insight into what they consider math ability to be, who should claim it, and whether or not math ability is "normal" or beneficial	surveys, interviews	former students	Aug-Nov2009 (interviews)
b. Do they see being mathematically able normal for women? For men?	math deviance discourse	Same as above	interviews	former students	Aug-Nov2009 (interviews)
c. Do the women see social benefits from being mathematically able?	math deviance discourse, math power discourse	Same as above	interviews	former students	Aug-Nov2009 (interviews)

d. Have the women had any negative experiences with being a mathematically able woman?	math deviance discourse	Negative experiences will provide a window into the broader dominant discourse about math ability and deviance	interviews	former students	Aug-Nov2009 (interviews)
e. Do the women feel that they belong in mathematics? Do they feel welcomed as women?	math deviance discourse, math discourse, sexuality	This will explore the relationship between the math, math deviance, and sexuality discourses	interviews	former students	Aug-Nov2009 (interviews)
f. If the women are in mathematics careers, is this choice supported by their family and friends?	math deviance discourse, sexuality	Whether or not family and friends support their decisions will impact the choices participants make	interviews	former students	Aug-Nov2009 (interviews)
g. Which discourses were present that challenged or reproduced the dominant discourse about mathematical ability as deviance?	math deviance discourse	Is this issue addressed directly or indirectly in the program?	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
8. Did consciousness-raising occur?					
a. Did the girls have opportunities to talk and share their gendered experiences with other girls and women?	consciousness raising	Need to know if the single-sex environment provided more opportunities for this, and if these experiences played a significant role in decisions/perceptions	field obs, interviews	current students current teachers former students	July 2009 (obs) Aug-Nov2009 (interviews)
b. Did the single-sex environment somehow encourage such conversations to occur?	consciousness raising	Would or do those conversations occur in other settings? If so, when and what structural supports must be in place to make that happen?	interviews	former students	Aug-Nov2009 (interviews)
c. Did the girls gain a new consciousness about either the role as women in our society, or their role as women in mathematics specifically?	consciousness raising	Need to understand how their experience in the program impacted other parts of their lives as women	interviews	former students	Aug-Nov2009 (interviews)
d. Did the girls become more aware of the injustices that women face in our society? Did they learn new skills and strategies to fight for gender equality in their lives?	consciousness raising	Need to determine if consciousness-raising explicit and if the participants were given the strategies to fight back	interviews	former students	Aug-Nov2009 (interviews)
e. Did that consciousness raising make mathematics more or less appealing for the girls?	consciousness raising	Need to determine if giving girls the "reality of the situation" of male-dominated mathematics is encouraging or discouraging for the girls	interviews	former students	Aug-Nov2009 (interviews)
f. Do the experiences in the program give the girls' skills to be critical of dominant discourses in other parts of their lives?	consciousness raising	In order to understand how consciousness raising occurs, need to determine if consciousness-raising experiences translate to other parts of the women's lives	interviews	former students	Aug-Nov2009 (interviews)
d. How does exposure to those discourses affect their experience in the math field? Do they act as change agents within the field, or do they reproduce the dominant discourses?	consciousness raising	Since my central research question is about long-term effects, I will need to understand how their participation in the program impacted their current experiences in the field of math--are they changing mathematics or not?	interviews	former students	Aug-Nov2009 (interviews)

Table 3. Theoretical Concepts Operationalized

Theoretical Concept	What it will look like in the data (a.k.a. How I will know it when I see it)
Math Discourse	any time the discipline of mathematics and school mathematics is talked about; observations made about how mathematics is practiced; references to the "way math is," what math is, what is valued or expected in mathematics; references to traditional vs. reform math, competitiveness, gendered stereotyped subjects, etc.
Math Ability Discourse	any time math ability is talked about; references to participants' own math ability or their beliefs about the math abilities of others; discussions of scientific statistics about gendered differences in math ability or reference to having or not having a "math gene"
Math Deviance Discourse	any reference to math ability as normal or deviant; references to "math nerds", fitting it, standing out, being supported; discussion of women's role in mathematics and absence from mathematics; discussion of female role models in mathematics; belonging; discussion of balancing family and social life or conflicting roles; isolation of mathematics
Math Power Discourse	any references to social power acquired or not accessed because of math ability; discussions of valuing or devaluing of mathematics; evidence of feeling guilty about not liking mathematics
Sexuality Discourse	any references to gender roles; observations of gendered "performances", appearance, or gender stereotypes; references to gender expectations, family obligations, social pressures; references to sexism, stereotypically female traits, "helping people," being "real" women; references to sexuality; discussion of working in male dominated field; discussion of single-sex environment
Consciousness-Raising	any references to instances where women developed a new understanding of their social position through conversations with other women; references to learning new skills or strategies to "fight back"; discussions of becoming aware, or feeling empowered or discouraged discussion of experiences with sexism

Field Site

The research context of this study was a SummerMath program for high school girls housed on the campus of a small New England liberal arts college. This program, called SummerMath, is an intensive, four-week mathematics program for girls entering grades 9-12 (Lacampagne, et al., 2007). During the summer of 2001, fifty-eight girls of diverse geographical, racial, and socioeconomic backgrounds were enrolled in the program (Anderson, 2005). SummerMath has strong relationships with several inner city schools, provides scholarships for low-income participants, and as a result, often as up to 70% minority students enrolled each summer (Morrow, 1996). The program, which began in 1982, provides girls of all mathematical abilities an opportunity to experience math in a fundamentally different way than they have in traditional classrooms

(Anderson, 2005). On the SummerMath website, the program is described in the following way:

> At SummerMath you won't just sit in class listening to lectures, and you won't spend hours struggling with math problems by yourself. In each class you will work in pairs, and use your hands, your eyes, your imagination, and each other to discover how math is applied to everyday life. Your instructors and classmates will listen to you and take you seriously. When you have questions, they will work with you to understand. It is a work in which creativity and problem-solving replace lectures and formulas. A typical day at SummerMath will be fun, challenging, and varied. Many students find that friendships made at SummerMath last for years (SummerMath, 2009).

One of the most obvious ways that SummerMath differs from most traditional classrooms is its single-sex learning environment. Without the presence of boys, it is thought that girls are more likely to speak up in class, to realize that girls are just as capable of doing mathematics as boys are, and to form relationships with other girls and women who like mathematics (Morrow & Morrow, 1995). The girls are taught predominantly by female teachers, and are provided with opportunities to meet and hear presentations from female mathematicians (Morrow, 1996). This not only gives the girls insight into the types of careers that are available in mathematics, but it also allows the girls to see that mathematics is not just for men.

In addition to the single-sex learning environment, the way that mathematics is taught diverges from the didactic methods used in traditional mathematics classrooms. First, teachers act as facilitators or coaches, rather than mathematical authorities (Anderson, 2005). Further, each class focuses on problem posing and problem solving instead of the more traditional method of lecture on a particular mathematical process and then independent rehearsal of that process (Morrow & Morrow, 1995). Students learn to engage in argumentation and justification, while simultaneously operating from a “believing mode” rather than one of disbelief (Morrow & Morrow, 1995). In this way, the girls send the message to each other that they trust that they have valuable ideas and will give each other the opportunities to share them. Similarly, the students rarely work on mathematical tasks alone (Anderson, 2005). Students are assigned partners for each task, and are encouraged to collaborate with other groups whenever necessary. Finally, the program offers confidence-building workshops where the girls examine their own mathematical biographies and their gendered relationship with mathematics (Anderson, 2005). In those sessions, the girls begin to raise their awareness about the messages they have been sent about their own math ability, and acquire the skills necessary to challenge those messages.

Participants

The participants in this study were selected from the population of SummerMath students who attended the program during the summers of 2000. That population of students was selected because they would most likely have completed a four-year undergraduate career and would already be either in the workforce or advanced graduate school by the time the research was conducted in the fall of 2009.

A sample of nine participants was selected from the total of 39 SummerMath students that made up the 2000 student population. According to Seidman (2006), there are two ways to know if you have enough participants: sufficiency and saturation. Specifically, for sufficiency to be met, there must be “sufficient numbers to reflect the range of participants and sites that make up the population so that others outside of the sample might have a chance to connect to the experiences of those in it” (Seidman, 2006, 55). Saturation is met if the researcher begins hearing the same information repeated by participants. I believe that the nine participants met the criteria for both sufficiency and saturation. Participants were chosen using a purposeful sampling technique. "Purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned" (Merriam, 1998, 61). While random sampling might be the gold star of scientific research, it was not possible in this situation. For, the concept of randomization requires a large sample size. Further, in this study participants needed to consent to a rather lengthy interview process, which automatically introduced an element of self-selection. With this in mind, nine participants were identified that were representative of the relative demographics of the larger population of SummerMath students. Using Seidman's (2006) concept of "maximum variation sampling," I identified the variables that were most significant to make the sample representative of the total population of students. While not exhaustive, some of variables that I used to consider participants for selection are as follows: race, SES, single-sex or coeducational high school attendance, single-sex or coeducational college attendance, math and non-math careers, and positive and negative post-survey results. Please refer to Table 4 for biographical information on each participant included in this study.

Table 4. Participants

Name	Race	Family of Math	Math in Career	Single-Sex College	Math Confidence	Geographical Region
Amala	Latina	no	no	no	very strong	Northeast-urban
Casey	Latina	no	no	yes	moderate	Northeast-urban
Catherine	Caucasian	no	no	no	weak	Midwest-suburban
Grace	Black	yes	yes	no	very strong	Northeast-urban
Harper	Caucasian/Asian	yes	yes	no	very strong	Northwest-suburban
Katelyn	Caucasian	no	no	no	weak	Northeast-urban
Molly	Indian/Asian Am.	yes	no	yes	moderate	Northeast-rural
Rachel	Caucasian	no	no	no	moderate	Southeast-rural
Ryan	Black/Caucasian	no	no	yes	weak	Northeast-urban

Observations

The first step in this research project was the field observations of one of the courses offered in the SummerMath program. Observations are beneficial for a variety of reasons. First, "as an outsider an observer will notice things that have become routine to the participants themselves, things that may lead to understanding the context" (Merriam, 1998, 96). Second, "observations are also conducted to triangulate emerging findings: that is, they are used in conjunction with interviewing and document analysis to substantiate the findings" (Merriam, 1998, 96). For this study, the primary purpose of the observations was to familiarize myself with the summer mathematics program more generally, ensure that the program is both reform-based and incorporates a feminist pedagogy, and to verify what participants recollected about their experiences in the program. The observations allowed me to ask more thoughtful questions of my participants during the interview phase of data collection, as I was much more knowledgeable about all facets of the program.

As a non-participant observer, I took field notes using "thick description" (Geertz, 1973). The idea of "thick description," borrowed from Ryle (1971), refers to the notion that to describe a behavior without considering its context will tell you very little about it, because the same behavior in different contexts can have very different meanings. I incorporated various strategies to help make my field notes representative of both the behaviors and contexts that I was observing. Using Taylor and Bogdan's (1984) suggestion, I gradually "shift[ed] from a wide angle to a narrow angle lens" (in Merriam, 1998, 105). While observing the setting, I included a detailed description of the setting, the people, and used direct quotations. I also made a map of the setting, and employed other quantifiable observation techniques to help familiarize myself with the setting. For, "counting, census-taking, and mapping are all ways of obtaining a more accurate picture of the presence of people, places, and things in social space in the early stages of field work when researchers capacity in the local language and access to local assistance are limited" (Schensul, Schensul, & LeCompte, 1999, 102). In addition, I recorded my observer comments in brackets, embedded in my field notes. In that way, I was able to record my first impressions, emotional reactions, and reflections. During analysis, I was able to refer back to those comments for insights into my thought process, be reminded of themes that I wanted to explore, and be aware of any biases that might have made me overlook important information.

Surveys

The second form of data collection was the pre- and post-surveys that were completed by each participant in the summer program. One of the strengths of using survey data is the fact that "the data clearly indicate that sensitive information is more frequently, and almost certainly more accurately, reported in self-administered modes than when interviewers ask the questions" (Fowler, 2002, 64). Therefore, when used in conjunction with in-depth interviews, surveys can improve the validity of the data collected.

This particular survey was developed by the program, not by this researcher, and contained both open and closed questions. There are several advantages to using open questions in survey instruments:

1. can "obtain answers that were unanticipated"
2. "may describe more closely the real views of the respondents"
3. "respondents like the opportunity to answer some questions in their own words" (Fowler, 2002, 91)

While open questions may have more validity, closed questions tend to have more reliability and allow participants responses to be more easily compared (Fowler, 2002). Most of the closed questions employed in the survey were modified from the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976), which originally included 173 items, all on a 5-point likert scale, measuring eight affective variables:

1. attitudes toward success in mathematics scale (AS)
2. mathematics as a male domain (MD)
3. mother (M)
4. father (F)
5. teacher (T)
6. confidence in learning mathematics scale (C)
7. mathematics anxiety scale (A)
8. effectance motivation scale in mathematics (E)
9. mathematics usefulness scale (U) (Fennema & Sherman, 1976)

The use of this survey served several purposes in this study. First, the closed questions on the survey were analyzed quantitatively using statistical analysis to determine if there were significant differences between pre- and post- responses. Second, the open questions (essays) from the survey were analyzed qualitatively, using thematic coding. The themes that were derived from that process helped determine the types of questions that were asked during the interview process. Third, the surveys allowed the triangulation of findings through the comparison of survey and interview responses. Finally, the surveys themselves were used as an elicitation device during the interview process, as participants were asked to reflect on their responses to the survey, and asked to make meaning of those responses.

Research has shown that "small events that have less impact are more likely to be forgotten than more significant events; recent events are reported better than events that occurred in the more distant past" (Fowler, 2002, 98). This provides a powerful rationale for using both survey data and interviews. For, the surveys can offer valuable information about what the participants' attitudes and perceptions were immediately following the program. Since this survey was administered right after the experience occurred, the information should be more accurate than if asked them to recollect on those experiences nine years later. Similarly, since we know that only significant memories tend to persist over time, what the participants are able to recall in an interview provides insight into what were the most significant events for those individuals.

Phenomenological Interviews

While both the field observations and surveys provided valuable information about the SummerMath program and its participants, the heart of this research project was the phenomenological interviews. In-depth phenomenological interviews combine life-history and in-depth interviewing by using open-ended questions in an attempt to encourage participants to reconstruct their experience (Seidman, 2006). The primary purpose of interviewing participants is to "find out from them those things we cannot directly observe… to allow us to enter into the other person's perspective" (Merriam, 1998, 72). A benefit of interviewing is that it can provide a context for people's behavior and help interviewers understand the lived experience of participants. If limited to only observations, we would know what types of behaviors people engaged in, but we wouldn't know why and we would know what meaning those behaviors had for an individual. As Seidman (2006) points out, "individuals' consciousness gives access to the most complicated social and educational issues, because social and educational issues are abstractions based on the concrete experience of people" (7). But perhaps even more importantly, observations do not provide an opportunity for participants to make meaning of their own experiences. One of the goals of feminist research is to help girls and a women "understand and transform their place in mathematics education" (Fennema & Hart, 1994, 655). Interviewing can be a tool used to achieve that lofty goal as participants tell stories about their experiences. For, "telling stories is essentially a meaning-making process… In order to give the details of their experience a beginning, middle, and end, people must reflect on their experience" (Seidman, 2006, 7). In that way, participants engage in the meaning-making process along with the researcher, reflecting on their own experiences, and thus, learning from them. Some would argue that this is a form of consciousness-raising, a critical instrument for feminist reform.

By definition, phenomenological research is typically conducted in a three-interview format, as was employed in this study. All participants were interviewed three times, each for 90 minutes, spaced one day to one week apart. The two most obvious benefits of such an interview schedule is that it "reduces the impact of possibly idiosyncratic interviews" (Seidman, 2006, 21) and allows for the interviewer to establish a relationship with the participant. The face-to-face interviews were conducted in a location chosen by the participants, usually in a local coffee shop. In the event that a participant did not live within close proximity to the researcher, interviews were conducted over the phone. All interviews were tape recorded and transcribed verbatim.

The first interview, often called the "life history," is an effort to "put the participant's experience in context by asking him or her to tell as much as possible about him or herself in light of the topic up to the present time" (Seidman, 2006, 17). The second interview focuses on the present day lived experiences of the participant in the topic of study. During this interview, I asked participants to describe a typical day in their job, including their relationships with their co-workers. The third interview asks the participants to reflect on their experiences and extract meaning from them. "Making sense or making meaning requires the participants to look at how the factors in their lives interacted to bring them to their present situation" (Seidman, 2006, 18). Rather than the interviewer inferring what meaning their participants make from their experiences, she asks the participants to make that meaning for themselves.

Due to the open-ended nature of phenomenological interviews, a highly structured interview schedule is usually not appropriate. Instead, I have provided a general overview of the types of questions I asked during the three interviews:

Interview 1 (life history):

> How did the participant come to be in the career she is in now? A review of the participant's life history up to the present time, making sure to include a discussion of the SummerMath program as part of that history.

Interview 2 (contemporary experience):

> What was it like for the participant to be in the SummerMath program? What is it like for the participant to be in her current career? What are the details of the participant's experience in the SummerMath program? What are the details of her experience in her current career?

Interview 3 (reflection on meaning):

> What did it mean for the participant to be a part of the SummerMath program? What does it mean to the participant to be in her current career? Given what the participant has said in interviews 1 and 2, how does she make sense of her current career? How does she make sense of the responses she gave on her survey nine years ago?

Artifact Collection

Throughout the data collection process, I also gathered artifacts from the summer program site. For example, I collected an extensive body literature on the SummerMath program including program advertisements, and other documents that were used the year the participants attended the program. I was also given complete access to the curriculum that was used during the program, all teacher training documents, application forms, and other official program documents. I agree with Merriam (1998) when she claims that "one of the greatest advantages in using documentary material is its stability. Unlike interviewing and observation, the presence of the investigator does not alter what is being studied" (126). The benefit of using artifact collection is that it is "nonreactive" and allowed me to substantiate my field observations and the claims that the participants made about the program (Merriam, 1998, 126).

Reliability and Validity

As it is traditionally defined in positivist research, "reliability refers to replicability of research results over time, different sites and populations, and with different researchers (Schensul, Schensul, & LeCompte, 1999, 271). Yet, most qualitative researchers would agree that the concept of reliability is inappropriate for most qualitative work. Due to the long duration in the field and strong relationships built, it would be virtually impossible to replicate one's qualitative methods exactly. Instead, Merriam (1998) suggests that reliability be thought of as dependability or consistency. One of the ways to improve reliability is to do what Merriam (1998) calls an "audit trail," which is to thoroughly explain your methodology and research context clearly so others can understand whether or not the results might apply to their context. After all, "if we cannot expect others to replicate our account, the best we can do is explain how we arrived at our results" (Merriam, 1998, 207). For this study, I have attempted to clearly describe my methodology and give my rationale for using such methods. I have also clarified the context of my research so that there will be no mistake about what type of setting from which these results were found.

According to Schensul, Schensul, & LeCompte's (1999) definition, "validity is the degree to which researchers actually have discovered what they think their results show, and how applicable the results are to other populations" (271). Internal validity refers to how closely the findings match reality or how accurately a researcher is measuring what they think they are measuring (Merriam, 1998). Typically, qualitative research has high interval validity, simply because the researcher spends so much time in the field. In order to avoid threats to internal validity, researchers need to build trusting relationships with their participants, observe for long periods of time, be aware of observer effects, as well as use multiple researchers or multiple data sources (Schensul, Schensul, & LeCompte, 1999). For this study, I attempted to avoid threats to internal validity in several ways. First, I tried to form positive relationships with my participants in an effort to put them at ease. Second, I used field observations, surveys, interviews, and artifacts to triangulate my data. If I begin to notice inconsistencies among participants' responses, I looked to substantiate their claims through observation or other participants' interviews. Also, the three-interview format of phenomenological interviews accounted for any idiosyncratic interviews and allowed me to check for internal consistency. "Just as aeronautical engineers build mechanical and structural redundancy into airplanes and bridges, ethnographic researchers build redundancy into their data collection methods" (LeCompte & Schensul, 1999, 130-131).

While internal validity in qualitative research can be achieved fairly easily by taking appropriate precautions, external validity can be more difficult to achieve. External validity in qualitative research "is concerned with the extent to which the findings of one study can be applied to other situations" (Merriam, 1998, 207). In other words, it often refers to the generalizability of the results. One primary way that I tried to improve external validity was through providing thick description of my research context, my researcher role, and the data collected, so that readers can determine for themselves whether my findings would be generalizable to their specific context.

Researcher Subjectivity

As a 33 year-old, white, female researcher who is a former middle school math teacher, my perspective is subjective. While I have no previous experience working in a high school SummerMath program for girls, I attended an all-women's college. I am invested in this project because one of the reasons I left teaching was because I struggled to get my female students excited about mathematics. If my research was going to be valid at all, I needed to be aware of my own biases, my lens, and try to understand how my perspective and experiences might affect what I see and don't see in the field. Peshkin (1988) astutely asserts "untamed subjectivity mutes the emic voice" (21). The goal of my research is to gain the participants' perspective, and I could not accomplish that without being aware of my own. In other words, "by this consciousness I can possibly escape the thwarting biases that subjectivity engenders, while attaining the singular perspective its special persuasions promise" (Peshkin, 1988, 21). In an effort to "tame" my subjectivity throughout this project, I kept a researcher journal. I used that journal to record my thoughts and feelings about the project as data collection was in progress and during data analysis. Lastly, as I recorded my field notes, I also recorded my observer's comments in brackets, to keep them separate from the data. In this way, I attempted to keep my thoughts removed from the actual events that were occurring without losing or ignoring my own impressions. Since the researcher is the research instrument, recording my own thoughts and feelings was an important way to keep myself "calibrated."

Despite my best efforts to keep my subjectivities in check, they inevitably influenced the outcome of this study. For example, interviews with one of the participants were especially difficult because her responses were extremely brief. It was difficult not to take her reluctance to share details of her life personally, and I grew to dread our interviews. Similarly, after traveling long distances to interview participants, and investing money in hotel rooms, bus tickets, subway rides, and gas, I had certain expectations for those interviews. On several occasions I felt that the trip, and the expenses incurred to make the trip were “not worth it.” Needless to say, it was a challenge not to allow those feelings to interfere with our relationship. Finally, boredom was also a significant hurdle that I had to consciously manage, due to the inherent redundancy of the three interview format, the use of artifacts as elicitation devices, as well as my own familiarity with k-16 mathematics education. The challenge to “make the familiar strange” was one that I’m afraid I did not always successful meet during my interviews (Delamont, 2002, 51). I found it almost impossible to keep my experiences in k-16 math classes from intruding during both the collection and analysis of data. I constantly had to ask myself whether the conclusions I was drawing or the questions I was asking were really related to my participants’ actual responses, or due to my own personal experiences. I found this monitoring of my personal bias especially difficult when talking with a participant who had graduated from my alma mater. In fact, I found it easiest to interview those participants whose experiences were most different from my own. I was naturally curious to hear about the experiences of a participant who dropped out of high school, or what it was like for a black woman to navigate the world of white male accountants. For, when talking with those individuals, the questions I was asking felt more authentic. With some of the other participants who were more similar to me based on their race, educational experiences, etc., my questions felt more robotic, as if I were “testing” them to see if they said what I expected them to say. Keeping my researcher journal was particularly useful in identifying these danger areas, and allowed me to think critically about my role in the data collection and analysis process.

Lastly, part of my motivation for designing this research study was my commitment to both reform-based mathematics pedagogy and single-sex education. Before I began the study, I held certain beliefs that inevitably influenced what I was able to “see” in my data. At various points during my conversations with participants, I found their beliefs about mathematics to be personally offensive or threatening. As a former math teacher, there were times I felt defensive as participants criticized or stereotyped “all math teachers.” I was particularly sensitive to the participants’ disparaging comments about single-sex education and felt as if I was being personally attacked. Attending a women’s college is a large part of my identity, thus it was extremely difficult not to defend single-sex institutions during those conversations. Nonetheless, I think I learned more from the participants with whom I disagreed because I was forced to be more cognizant of my biases and perspectives.

Research Ethics and Protection of Participants

In any research project that utilizes human subjects, care must be taken to protect them from harm. For this study, I made great efforts to protect my participants’ privacy and to ensure that there was minimal or no-risk of involvement. Prior to conducting any observations or interviews, all participants were asked to sign a letter of informed consent. Students who were currently enrolled in the SummerMath program were required to obtain parental permission. The form clearly outlined what would be happening in the study, and informed them that they had the right to refuse to participate. The consent form explain that pseudonyms will be used to protect their identity, and the key that links participants pseudonyms with their true identity will be kept in a secure spot separate from the data. Finally, participants were informed that the tapes used during interviews will be destroyed after data analysis.

Data Analysis

Quantitative Data Analysis

In this section, the data analysis and results for the quantitative survey used in this study will be discussed. The survey was administered to participants on the first day and last day of the SummerMath program. The survey consisted of 50 items that were modified from the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976) and the Indiana Mathematics Beliefs Scales (Kloosterman & Stage, 1992).

Table 5. Quantitative Survey Items

Scale 1: Persistence/Confidence
*11. Math problems that take a long time don't bother me (5=STRONGLY AGREE)
*19. I feel I can do math problems that take a long time to complete
*27. I find I can do hard math problems if I just hang in there
6. If I can't do a math problem in a few minutes, I probably can't do it at all (1=STRONGLY AGREE)
3. If I can't solve a math problem quickly, I quit trying
8. I'm not very good at solving math problems that take a while to figure out
Scale 2: Usefulness of Mathematics
*34. I study mathematics because I know how useful it is (5=STRONGLY AGREE)
*43. Knowing mathematics will help me earn a living
*1. Mathematics is a worthwhile and necessary subject
*46. Mathematics will be important for me in my life's work
25. Mathematics is of no relevance to my life (1=STRONGLY AGREE)
14. Studying mathematics is a waste of time
Scale 3: Mathematics as a Male Domain
*13. I would trust a woman just as much as I would trust a man to figure out important calculations (5=STRONGLY AGREE)
*35. Males are not naturally better than females in mathematics
*36. Women are certainly logical enough to do well in mathematics
49. I would expect a woman mathematician to be a masculine type of person (1=STRONGLY AGREE)
17. It's hard to believe a female could be a genius in mathematics
30. Girls who enjoy math are a bit peculiar
Scale 4: Attitude Toward Success in Mathematics
*40. It would make me happy to be recognized as an excellent student in mathematics (5=STRONGLY AGREE)
*42. Being first in a mathematics competition would make me pleased
*38. Being regarded as smart in mathematics would be a great thing
45. Winning a prize in mathematics would make me feel unpleasantly conspicuous (1=STRONGLY AGREE)
16. If I had good grades in math, I would try to hide it
26. It would make people like me less if I were a really good math student
Scale 5: Teacher Scale
*47. My teachers think I'm the kind of person who could do well in mathematics (5=STRONGLY AGREE)
*4. My math teachers would encourage me to take all the math I can
*10. My math teachers have been interested in my progress in mathematics
22. I have found it hard to win the respect of math teachers (1=STRONGLY AGREE)
21. My teachers think advanced math is a waste of time for me
2. My teachers would think I wasn't serious if I told them I was interested in a career in science or math
Scale 6: Effectance Motivation
*7. Mathematics is enjoyable and stimulating to me (5=STRONGLY AGREE)
*48. When a question is left unanswered in math class, I continue to think about it afterward
*15. I am challenged by math problems I can't understand immediately
23. Math puzzles are boring (1=STRONGLY AGREE)
5. I don't understand how some people can spend so much time on math and seem to enjoy it
39. I would rather have someone give me the solution to a difficult math problem than have to work it…
Scale 7: Family
*33. My family thinks I'll need mathematics for what I want to do after I graduate from high school (5=STRONGLY AGREE)
*37. My family has always been interested in my progress in mathematics
*28. My family thinks I'm the kind of person who could do well in math
32. No one in my family likes to do math (1=STRONGLY AGREE)
50. My family thinks I need to know just a minimum amount of math
18. My family wouldn't encourage me to plan a career which involves math
Scale 8: Equitable Participation in Mathematics
*9. Anyone who works hard enough can have a career in mathematics and science (5=STRONGLY AGREE)
*24. Working hard can improve one's ability in math
*29. Generally my teachers think that anyone can succeed in math if they try hard enough
*41. My friends respect a hard working math student
31. My teachers generally think that some groups of people are more talented in math than others (1=STRONGLY AGREE)
12. Some groups of people are more talented in math than others
44. Some types of people don't belong in math or science careers
20. My friends think that working hard in math class is a waste of time
Additional Items
51. My confidence level in mathematics is (1=VERY)
52. My confidence level in using calculators is (1=VERY)
53. My confidence level in using computers is (1=VERY)
54. I have worked with classmates on math problems IN CLASS (1=often, 2=occasionally, 3=never)
55. I have worked with classmates on math problems OUTSIDE OF CLASS (1=often, 2=occasionally, 3=never)
56. I would like to work with classmates on math problems (1=often, 2=occasionally, 3=never)

Those 50 items were organized into 8 different attitudinal scales including: 1) Persistence/Confidence, 2) Usefulness of Mathematics, 3) Mathematics as a Male Domain, 4) Attitude Toward Success in Mathematics, 5) Teacher, 6) Effectance Motivation, 7) Family, and 8) Equitable Participation in Mathematics. All questions included a 5-point likert scale from "strongly agree" to "strongly disagree".

The first step in quantitative data analysis involved calculating the average or mean response to each item. In order to obtain scores for each subscale, it was necessary to reverse the ratings for all positively worded questions, as indicated by an asterisk (*) in Table 1. To interpret mean scores for positively worded questions, a score closer to 5 suggested strong agreement, while for negatively worded questions a score closer to 1 indicated agreement. In addition to those 50 items, an additional 6 items, not based on the Fennema-Sherman or Indiana Mathematics Beliefs Scales, were also included in the study.

The second step in quantitative data analysis was to determine the degree to which the data varied from the mean, which is determined through the calculation of standard deviation. A large standard deviation score for a particular item would indicate there was a great deal of variation among the participants' scores on that item. In other words, a large standard deviation would indicate variability in the girls' responses to that particular item.

In addition, a paired t-test was also performed to evaluate if the girls' attitudes changed over the course of the five-week program. The test was used to determine if there is a statistically significant difference between the pre- and post- test sample means for each item, which would suggest that the change is significant enough not to be due to chance (Fowler, 2002). If statistically significant ($p < .05$), the data could suggest that the single-sex reform-based summer mathematics program had a short-term impact on the eight affective variables being measured (Fennema & Sherman, 1976).

After the mean, standard deviation, and t-test score were calculated for each survey item individually, the scores for each subscale were also analyzed. The mean and standard deviation were calculated for each subscale and then t-tests were performed to determine statistical significance by subgroup.

Qualitative Data Analysis

Qualitative data analysis was ongoing in this study, beginning with the first piece of data collected. Armed with a guiding theoretical framework, but employing a predominantly bottom-up approach, my data analysis was a recursive process that blended both inductive and deductive theory building.

Using grounded theory as my central approach to data analysis, I identified patterns and themes in my data. Grounded theory, first introduced by Glaser & Strauss (1967), is a methodology that builds theory from qualitative data. Theories, or theoretical constructs, emerge from the data itself, as a researcher begins to see patterns and make connections across many different pieces of data. This differs greatly from traditional scientific research, in which a theoretical framework is developed and then applied to the research, creating a hypothesis and then designing a study to prove or disprove it. In grounded theory, categories are "systematically interrelated through statements of relationship to form a theoretical framework that explains some phenomenon" (Strauss & Corbin, 2008, 55). It is also commonly called the "constant comparative method" because during data analysis, hypotheses are constantly being verified by the data (Glaser & Strauss, 1967). In the end, the goal of grounded theory is to develop well-supported substantive theories.

The first step in the process of grounded theory is open coding. Open coding is a method used to “open up” the data to all possible meanings and interpretations (Corbin & Strauss, 2008). Data gets broken down into smaller parts and closely examined. Then, data is grouped and compared for similarities and differences, and then given conceptual names. It is then that conceptualization of the data occurs and the researcher must think abstractly about the data and the messages and relationships that might exist. The ultimate goal of open coding is to develop and refine research questions in order to direct or focus future data collection efforts. During open coding, categories are developed, and key concepts under each category are identified, but relationships between and among the categories or concepts are not necessarily declared. One technique that I used during the open coding process was the questioning of the meaning of a term used by participants. This allowed me to question my preconceived notions about a term, and forced me to consider all possible explanations.

An instrumental part of the open coding process is microanalysis. Microanalysis is simply described by Corbin & Strauss (2008) as a more detailed form of open coding. It is used like open coding to generate all possible ideas for the meaning of the data, and prevents researchers from running away with the first interpretation that they arrive at. During microanalysis, as interpretations are made, those interpretations will be checked with the rest of the data to specifically check the validity of that interpretation.

After open coding was complete, I began the process of axial and selective coding. Axial coding involves making connections between categories and subcategories. According to Strauss & Corbin (1998), "the purpose of axial coding is to being the process of reassembling data that were fractured during open coding" (124). Selective coding is essentially the process of theory building by integrating and refining the central category. Both forms of coding helped me to identify relationships between categories, make statements about the conditions under which each phenomenon or concept occurs, and generate a plausible theory or explanation of the concept.

Finally, perhaps one of the most instrumental methods used during the data analysis process was memo writing (Corbin & Strauss, 2008). Throughout the entire data analysis process, I systematically recorded my thoughts about what I was observing. That documentation not only provided a record of my data analysis process, making my analytic techniques transparent, but also encouraged me to consider multiple explanations for what I was observing. In this way, the research memo writing process served to reinforce the validity of my findings and ensure that I captured the essence of my participants' experiences.

Limitations of the Study

Of course, there were limitations to my study. First and foremost, the sample included in my study was essentially a convenience sample. There were many participants for whom I could not locate their current address or telephone number, and therefore did not have an equal opportunity to participate in the study. Also, I relied heavily on www.facebook.com to track down participant current information, which might have eliminated less technological savvy or less social individuals from my study. While I believe that I was fairly successful in selecting a sample that was representative of the overall SummerMath population, self-selection inevitably played an important role. These participants were overwhelming positive in their recollections of the SummerMath program. However, it is impossible to know whether or not the individuals who chose to participate in the study did so because they had a great affection for the SummerMath program. Perhaps those who declined to participate did so purely because they did not see their time at SummerMath as well-spent or beneficial. Or, other factors may have played a role in self-selection, such as amount of free time, openness, or interest in research.

Another limitation of the study was the fact that the study relied solely on interviews ten years after participating in the program. The design of the study could have been dramatically improved if interviews immediately after the program were also included in the study. Then, the persistence and similarity of their responses over time could have been measured. This study relied primarily on the recollections of participants, which can sometimes be unreliable, especially so many years later.

Finally, I was extremely fortunate to be granted access to the pre- and post-surveys that were administered 10 years ago. However, it is difficult to use the results from that survey data to draw any meaningful conclusions for several reasons. The most glaring reason is the fact that the sample size was considerably smaller than is required to achieve any real statistical power. Second, the information gleaned from those surveys was limited to short-term program outcomes, while the research questions in this study all pertained to long-term ones. Thus, the findings from those surveys, while providing a more robust picture of the phenomenon being studied, should be given only minimal consideration based on their significant limitations in scope.

This study examined one particular summer math program for high school girls at one particular point in time. Sample size was limited to only nine participants. In this paper, I have described the research context, the data collection and data analysis methods used in great detail. It is left to the readers of this study to determine whether these findings apply to their own situations or institutions. As with most case study research, these findings are not intended for broad generalization, but instead, to provide an in-depth understanding of one particular social unit.

Lessons in Data Collection

The process of researching and writing this dissertation was obviously a learning experience for me. As such, I made many mistakes along the way, and hopefully will learn from those mistakes and not repeat them in future research projects. The first mistake I made was having far too many research questions included in my research design. While I believe that my research questions were well aligned with my theoretical framework, having nine different questions to answer became extremely constraining as data collection progressed. Because there were so many questions to consider, I found it difficult to "see" unexpected findings. I had created a very loose interview protocol that was designed to answer my research questions. However, I realize now that by having so many research questions, it artificially constrained what was supposed to be an extremely open-ended phenomenological interview process. While the large number of research questions easily translated to clean categorical “buckets” which made data analysis more expedient, it was not necessarily more effective.

Another way that my data collection process could have been improved was to do more data analysis between interviews. Most of the time, I was able to do at least some cursory data analysis before having to conduct the second or third interview, but there were also times when that was simply not possible. On several occasions, I interviewed a participant on two consecutive days because of participant availability, logistics, or travel, and this dramatically limited my ability to fully analyze the data between interviews. It was obvious to me that for those participants for whom I had spent a significant amount of time analyzing their interview transcripts and generating follow-up questions, the interviews were much more successful and illuminative. In the future, should I decide to use a three-interview format, I will insist upon spreading those interviews out over several days, as was my original plan.

Similarly, my participants and I found the ambiguity of the third phenomenological interview very challenging. I believe that part of my difficulty with the third interview had to do with my lack of a clear understanding of what the goal of that interview was. I was asking the participants to make meaning of their experience in the SummerMath program in the context of their current lives. However, I frequently felt they had already answered that question briefly in the second interview, and I struggled to find ways to get them to expand on those earlier responses. As I said before, I think that part of my ineptitude came from my lack of a conceptual understanding of what purpose the third interview serves more generally, and more specifically, what I wanted to learn from them that I hadn’t heard already. If I use phenomenological interviews again in future research, I will need to be sure that my research question clearly merits a phenomenological approach. I will also need to spend more time reading transcripts of phenomenological interviews to ensure that I have developed a deep understanding of the approach. Needless to say, I thought I had done that prior to beginning this research, but inevitably, when asked to apply that understanding to my own project, my limited understanding was revealed.

Finally, I struggled when analyzing the surveys that someone else had created. Once I began analyzing the survey data, I quickly realized problems with some of the questions that were included. I also had great difficulty making any sweeping claims about my findings due to the small sample size. While there were many statistically significant differences between the participants pre- and post- survey responses, I had great difficulty including those results in my findings. For, it seemed almost disingenuous to use results from such a small sample size to substantiate my qualitative findings or answer my research questions. While I really appreciated the potential breadth and depth that a mixed-method approach afforded, I need to better articulate the purpose that each data source serves in answering my research questions. And most importantly, when using quantitative data, I need to make sure that my sample size is large enough that I feel comfortable using the results to substantiate my findings. Otherwise, it seems almost meaningless to include them.

Summary

The purpose of this study is to determine the long-term impact of a single-sex reform-based summer mathematics program on high school girls. In an effort to answer this research question, I designed a mixed-method study that utilized a variety of data collection techniques including pre- and post-surveys, field observations, phenomenological interviews, and artifact collection. Nine participants who were enrolled in a summer mathematics program for high school girls in 2000 were purposefully selected to best represent the overall population of program participants during that time period. The quantitative survey data collected was analyzed using both descriptive statistics and a paired t-test to test. Themes and patterns were explored in the qualitative data using a blend of inductive and deductive techniques, while drawing heavily grounded theory methodology.

CHAPTER 4

QUANTITATIVE RESULTS

In this chapter, the data analysis and results for the quantitative survey used in this study will be discussed. The survey was administered to participants on the first day and last day of the SummerMath program. As discussed in Chapter 3, the survey consisted of 50 items that were modified from the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976) and the Indiana Mathematics Beliefs Scales (Kloosterman & Stage, 1992). Those 50 items were organized into 8 different attitudinal scales including: 1) Persistence/Confidence, 2) Usefulness of Mathematics, 3) Mathematics as a Male Domain, 4) Attitude Toward Success in Mathematics, 5) Teacher, 6) Effectance Motivation, 7) Family, and 8) Equitable Participation in Mathematics. All questions included a 5-point likert scale from "strongly agree" to "strongly disagree". In order to obtain scores for each subscale, it was necessary to reverse the ratings for all positively worded questions, as indicated by an asterisk (*) in Table 1. To interpret mean scores for positively worded questions, a score closer to 5 suggests strong agreement, while for negatively worded questions a score closer to 1 indicates agreement. In addition to those 50 items, an additional 6 items, not based on the Fennema-Sherman or Indiana Mathematics Beliefs Scales, were also included in the study.

For each item included in the survey, the mean and standard deviation was calculated.   In addition, a paired t-test was also performed to evaluate if the girls' attitudes changed over the course of the five week program. The test was used to determine if there is a statistically significant difference between the pre- and post- test sample means for each item, which would suggest that the change is significant enough not to be due to chance (Fowler, 2002). Table 5 shows mean, change in mean, and standard deviation scores for each of the pre-test and post-test items. It also shows the t score and p value associated for each item of the survey. Finally, the items are grouped by subscale and the mean, change in mean, standard deviation, and t score and p value for each subscale are provided.

Table 6. Pre- and Post-Survey Results

Item	Pre-Mean	Post-Mean	Change in Mean	SD	t	p
Scale 1: Persistence/Confidence						
*11. Math problems that take a long time don't bother me (5=AGREE)	3.026	2.895	-0.132	1.143	-0.710	0.482
*19. I feel I can do math problems that take a long time to complete	3.579	3.947	0.368	0.913	2.488	0.017**
*27. I find I can do hard math problems if I just hang in there	4.079	4.263	0.184	1.062	1.070	0.292
6. If I can't do a math problem in a few minutes, I probably can't do it at all (1=AGREE)	4.079	4.290	0.211	1.189	1.091	0.282
3. If I can't solve a math problem quickly, I quit trying	3.895	3.974	0.079	1.323	0.368	0.715
8. I'm not very good at solving math problems that take a while to figure out	2.974	3.316	0.342	1.681	1.255	0.218
TOTAL	22.684	23.500	0.816	4.234	1.823	0.077
Scale 2: Usefulness of Mathematics						
*34. I study mathematics because I know how useful it is (5=AGREE)	4.211	4.132	-0.079	1.050	-0.464	0.646
*43. Knowing mathematics will help me earn a living	4.395	4.605	0.211	0.704	1.845	0.073
*1. Mathematics is a worthwhile and necessary subject	4.474	4.816	0.342	0.583	3.621	0.001**
*46. Mathematics will be important for me in my life's work	2.290	1.763	-0.526	1.268	-2.559	0.015**
25. Mathematics is of no relevance to my life (1=AGREE)	4.132	4.368	0.237	1.240	1.178	0.246
14. Studying mathematics is a waste of time	4.316	4.605	-0.290	0.768	2.324	0.026**
TOTAL	25.237	26.763	1.526	3.791	3.079	0.004**
Scale 3: Mathematics as a Male Domain						
*13. I would trust a woman just as much as I would trust a man to figure out important calculations (5=AGREE)	4.842	4.816	-0.026	1.026	-0.158	0.875
*35. Males are not naturally better than females in mathematics	3.684	4.316	0.632	1.979	1.968	0.057
*36. Women are certainly logical enough to do well in mathematics	4.790	4.790	0.000	0.658	0.000	1.000
49. I would expect a woman mathematician to be a masculine type of person (1=AGREE)	4.553	4.684	0.132	0.777	1.044	0.303
17. It's hard to believe a female could be a genius in mathematics	4.868	4.947	0.079	0.359	1.356	0.183
30. Girls who enjoy math are a bit peculiar	4.132	4.684	0.553	0.921	3.698	0.001**
TOTAL	26.868	28.237	1.368	2.849	2.856	0.007**
Scale 4: Attitude Toward Success in Mathematics						
*40. It would make me happy to be recognized as an excellent student in mathematics (5=AGREE)	4.711	4.737	0.026	0.545	0.298	0.767
*42. Being first in a mathematics competition would make me pleased	4.579	4.658	0.079	0.712	0.683	0.499
*38. Being regarded as smart in mathematics would be a great thing	4.658	4.790	0.132	0.623	1.303	0.201
45. Winning a prize in mathematics would make me feel unpleasantly conspicuous (1=AGREE)	4.108	4.211	0.081	0.983	0.502	0.619
16. If I had good grades in math, I would try to hide it	4.553	4.737	0.184	1.062	1.070	0.292
26. It would make people like me less if I were a really good math student	4.605	4.684	0.079	0.712	0.683	0.499
TOTAL	27.105	27.816	0.711	2.710	1.765	0.086

Table 6. Pre- and Post-Survey Results (continued)

Scale 5: Teacher Scale						
*47. My teachers think I'm the kind of person who could do well in mathematics (5=AGREE)	4.079	4.105	0.026	0.972	0.167	0.868
*4. My math teachers would encourage me to take all the math I can	4.079	4.237	0.158	0.916	1.062	0.295
*10. My math teachers have been interested in my progress in mathematics	3.605	3.763	0.158	1.516	0.642	0.525
22. I have found it hard to win the respect of math teachers (1=AGREE)	3.658	3.684	0.026	1.568	0.103	0.918
21. My teachers think advanced math is a waste of time for me	4.053	4.184	0.132	0.777	1.044	0.303
2. My teachers would think I wasn't serious if I told them I was interested in a career in science or math	3.737	3.921	0.184	1.270	0.894	0.377
TOTAL	23.211	23.895	0.684	4.793	1.299	0.202
Scale 6: Effectance Motivation						
*7. Mathematics is enjoyable and stimulating to me (5=AGREE)	3.026	3.316	0.290	1.011	1.765	0.086
*48. When a question is left unanswered in math class, I continue to think about it afterward	3.447	3.184	-0.263	1.083	-1.498	0.143
*15. I am challenged by math problems I can't understand immediately	3.658	3.605	-0.053	1.293	-0.251	0.803
23. Math puzzles are boring (1=AGREE)	3.342	3.842	0.500	0.980	3.147	0.003**
5. I don't understand how some people can spend so much time on math and seem to enjoy it	3.000	3.763	0.763	1.384	3.399	0.002**
39. I would rather have someone give me the solution to a difficult math problem than have to work it	3.579	3.684	0.105	1.110	0.585	0.562
TOTAL	20.053	21.395	1.342	4.976	2.414	0.021**
Scale 7: Family						
*33. My family thinks I'll need mathematics for what I want to do after I graduate from high school (5=AGREE)	4.079	4.211	0.132	0.875	0.927	0.360
*37. My family has always been interested in my progress in mathematics	4.342	4.605	0.263	0.828	1.959	0.058
*28. My family thinks I'm the kind of person who could do well in math	4.184	4.290	0.105	0.953	0.681	0.500
32. No one in my family likes to do math (1=AGREE)	4.026	4.162	0.135	0.855	0.961	0.343
50. My family thinks I need to know just a minimum amount of math	4.105	4.474	0.368	1.101	2.063	0.046**
18. My family wouldn't encourage me to plan a career which involves math	4.658	4.711	0.053	0.733	0.442	0.661
TOTAL	25.395	26.342	0.947	4.067	2.031	0.050**
Scale 8: Equitable Participation in Mathematics						
*9. Anyone who works hard enough can have a career in mathematics and science (5=AGREE)	4.026	4.132	0.105	1.539	0.422	0.676
*24. Working hard can improve one's ability in math	4.605	4.684	0.079	0.673	0.723	0.474
*29. Generally my teachers think that anyone can succeed in math if they try hard enough	4.421	4.053	-0.368	1.195	-1.900	0.065
*41. My friends respect a hard working math student	3.868	4.105	0.237	1.101	1.326	0.193
31. My teachers generally think that some groups of people are more talented in math than others (1=AGREE)	2.500	2.868	0.368	1.282	1.771	0.085
12. Some groups of people are more talented in math than others	1.974	2.158	0.184	1.431	0.794	0.432
44. Some types of people don't belong in math or science careers	3.026	3.500	0.474	1.466	1.992	0.054
20. My friends think that working hard in math class is a waste of time	3.658	4.290	0.632	1.101	3.537	0.001**
TOTAL	28.079	29.790	1.711	4.812	2.224	0.032**
Additional Items						
51. My confidence level in mathematics is (1=very)	2.158	1.684	0.684	1.118	3.774	0.001**
52. My confidence level in using calculators is (1=very)	1.790	1.553	0.211	0.704	1.845	0.073
53. My confidence level in using computers is (1=very)	2.105	2.079	0.474	0.951	3.070	0.000**
54. I have worked with classmates on math problems IN CLASS (1=often, 2=occasionally, 3=never)	1.658	1.711	0.237	0.490	2.982	0.005**
55. I have worked with classmates on math problems OUTSIDE OF CLASS (1=often, 2=occasionally, 3=never)	1.474	1.432	0.026	0.545	0.298	0.767
56. I would like to work with classmates on math problems (1=often, 2=occasionally, 3=never)	1.105	1.054	-0.053	0.567	-0.572	0.571

*reverse scored

**p < .05

The results in Table 1 indicate that for 12 of the 56 total questions, the changes in the mean from pre- to post- test were statistically significant. In particular, the increase in the girls' confidence level in mathematics was statistically significant (t (37)=-3.774, p=.010), along with their increased confidence level in using computers (t (37)=-3.07, p=.004). These results suggest that this single-sex reform-based summer mathematics program had a least a short-term impact on their confidence level in those two subjects.

In addition to statistical significance by item, the results also indicate that for 5 of the 8 grouped subscales, changes in mean were also statistically significant. To begin, the increase in girls' perception of the Usefulness of Mathematics (Scale 2) was statistically significant (t (37)=3.079, p=.004). It is interesting to note that this subscale had the largest number of individual items with statistical significance. These results strongly suggest that the SummerMath program had a positive short-term impact on the girls' beliefs about the usefulness of mathematics.

The girls' also reported a statistically significant decrease in their perception of Mathematics as a Male Domain (Scale 3) (t (37)=-2.856, p=-.007). It makes sense that being around a large group of girls and women who like mathematics would result in beliefs that girls belong in mathematics. In particular, the girls' changes in means indicate that they were less likely to agree that "girls who enjoy mathematics are a bit peculiar" (t (37)=3.698, p=.001). In other words, the SummerMath program normalized math ability for these participants.

The third subscale that was statistically significant was Effectance Motivation (Scale 6) (t (37)=2.414, p=.021). This result suggests that the girls' found math more intrinsically motivating and enjoyable after attending the SummerMath program. However, while this represents a significant increase, it should be noted that the girls' overall motivation scores were still relatively low, suggesting an area for improvement.

The Family subscale (Scale 7) was also statistically significant ($t\ (37)=2.031$, $p=.050$) with participants reporting more family support for mathematics after the program. At first glance, this result was surprising. However, it is possible that by attending the SummerMath program, students engaged in more conversations with their parents around mathematics education, which resulted in a change in their perception of parental support.

Finally, the girls reported a statistically significant increase in their beliefs about Equitable Participation in Mathematics (Scale 8) ($t\ (37)=2.224$, $p=.032$). This refers to their ideas about whether or not anyone can succeed in mathematics. In general, it appears that participating in the SummerMath program encouraged girls to believe that if one works hard enough, she can be successful in mathematics. The girls' scores on the other subscales did not increase significantly over the five week period.

Overall, these results suggest that the SummerMath program had a modest short-term impact on at least 5 affective variables being measured. Most significantly, these results indicate that the single-sex reform-based program made participants see mathematics as more useful, more enjoyable, and more appropriate for girls.

CHAPTER 5

DOMINANT DISCOURSES

Introduction

In this chapter, the results of the qualitative data will be discussed. While my initial research question focuses primarily on the impact of the SummerMath program, I have chosen to organize this chapter around the five primary discourses that were identified in my data, and their corresponding themes. In particular, I will discuss how the discourses found in the participants' interviews expand upon the theoretical framework originally presented in Chapter 1 (see Figure 4).

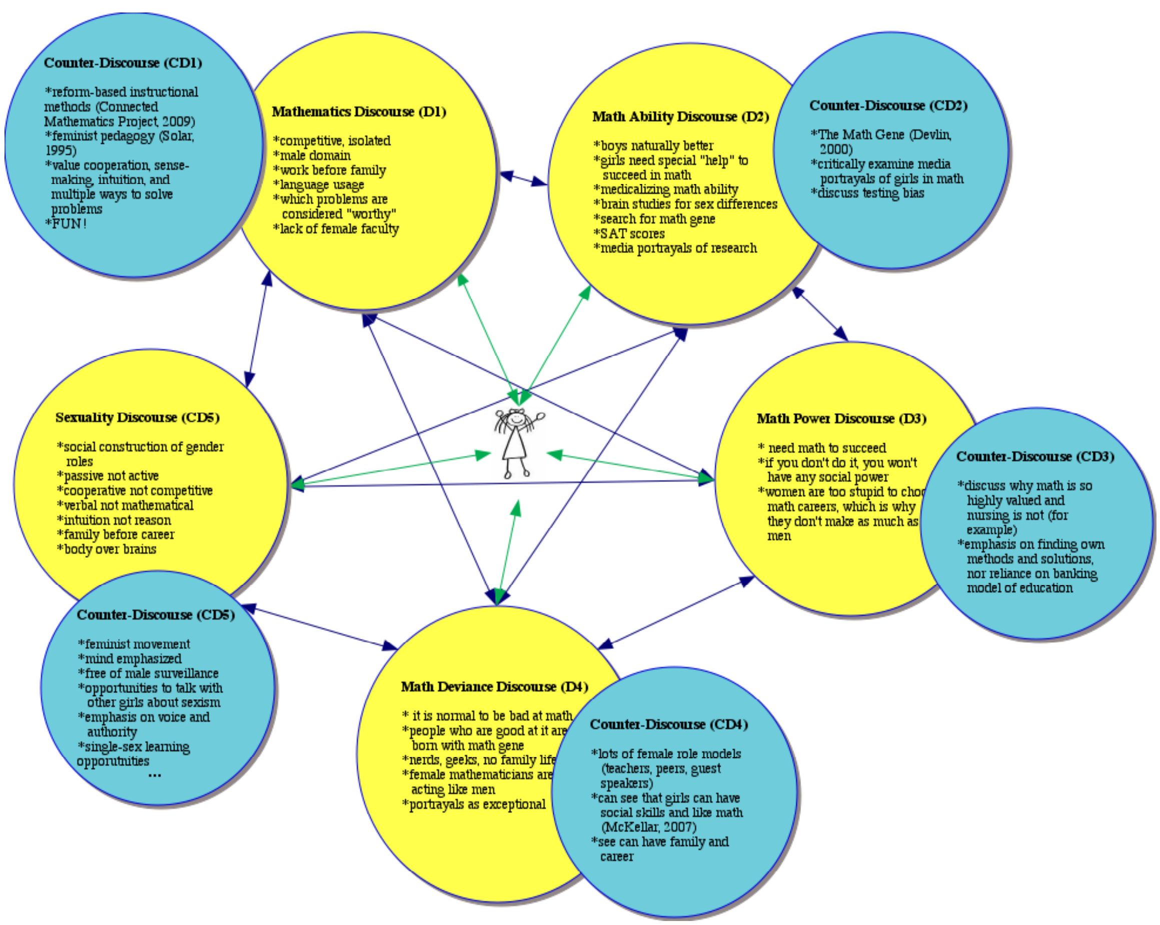


Figure 4. Competing Discourses for Girls and Women in Mathematics

Mathematics Discourse

As discussed in Chapter 1, the mathematics discourse (see D1 in Figure 4) involves how mathematics as a field is talked about, what counts as mathematics, what it is used for, and who should do it. Throughout the interviews, participants repeatedly recounted their mathematical experiences prior to and after attending the SummerMath program. Their comments on those experiences can be divided into two primary categories, including how math is taught, and how math is practiced. I will begin by discussing the major themes that emerged as participants reflected on how math was taught to them. The three themes that emerged from the data include obedience, unconnected teaching and learning, and feeling unsupported.

Taught

Obedience

As participants began sharing their mathematical histories, one of the more obvious themes that emerged was one of obedience (see Appendix A). Obedience will be defined, for the purposes of this study, as following orders given by a perceived authority figure. Frequently, obedience involves following a predetermined set of commands given by a person in power. The obedient person follows the directions in an unquestioning way, deferring responsibility and decision making to the person in authority. In situations of high obedience, there is only one expected behavior in any given situation, and all persons involved are expected to respond in the exact same ways. In this way, individuality is all but eliminated.

Obedience took the form of highly regulated, rigid, and teacher-directed instruction in these mathematics classrooms. Consistent with the findings of Boaler & Greeno (2000) and Stigler & Hebert (1997), these women described their experiences in mathematics classrooms as procedural and anti-intellectual. The role of the student in these mathematics classes was characterized by rule-following, compliance, memorization and regurgitation. Based on participant's common stories, the following illustrates a typical day of mathematics class, in the words of my participants:

> We'd sit in rows. The teacher would usually start class by going over the homework. She'd give us the answers and we'd write them down (Amala).
> Then we'd take notes on the new lesson (Grace).
> The teacher would explain the new procedure, giving several examples. Then we'd be asked to complete one as a class (Rachel).
> Then we'd do exercises (Molly).
> After the lesson, we'd start the homework, which was usually about 20 questions practicing what we'd just learned in class (Harper).
> It was boring, but really easy to do well as long as you followed the steps (Ryan).

The participants' mathematics classes required very little independent thought. Instead, students were expected to memorize specific procedures and be able to identify which types of problems can be solved using that procedure. Many of the participants passionately resisted this emphasis on memorizing steps or procedures.

> And it was like, what? I felt like it was just a whole bunch of equations and I felt like you just had to memorize equations. There was nothing, there was nothing to understand, it was just equations. There was no meat to it (Amala).

> There was a lot of memorizing of equations that you had to apply to it and that didn't really work for me. And I would, even if I got help, and the teacher explained something to me, like the next day or two days later, it would be out of my head (Katelyn).

> The teacher, he just kind of gave us the proofs and said this is what it is, memorize it, spit it back out. And, I just, I didn't think it was fun (Casey).

Rachel speculated that the recent emphasis on standardized testing resulted in more of an emphasis on memorization and regurgitation, and less of a focus on conceptual understanding.

> When we were in high school, this was when all of the No Child Left Behind was starting to take place. So they were really starting to switch over to the, you know, we've got input this into your brain so then you can be able to spit it back out on a test.

In all of these retellings, the role of the teacher was the mathematical authority who gave students knowledge. The teacher did most of the talking, and was responsible for determining what are acceptable methods and solutions. Participants explained that they rarely questioned what their teacher was showing them. Instead, the primary role of the student was passive, requiring students to listen, take notes, and memorize various procedures. Such a process required very little cognitive demand because conceptual understanding was not required to be successful in the class.

In addition to viewing math class as requiring regurgitation of memorized facts, participants disliked the emphasis on finding the correct answer instead of on the problem solving process (see Appendix A). Amala explains that "it's stressed to you that you need to get the right answer." According to these participants, there was very little interest in how students arrived at the answer. As Molly describes her high school math classes, she explains that there was so much emphasis on right answers, that students would simply sit and wait for the correct answers to be given, and then they would write them down.

> Well, there was some lecturing, but there was a lot of worksheets being handed out, and then going over the answers together as a class. So even if you didn't know what the answer was, you would get it later in the class. We went over it. So, I think some kids just weren't motivated to do it because they knew they were going to get the answer. I think pretty much everyone did well in that class just because we would go over our homework and then hand it in. So you had a chance to write in the answers.

This is a common description of participants' experiences. Of course, one of the benefits of this model of teaching is that students can get immediate feedback on their work. However, the focus on getting the correct answer, without emphasis on methods used to find the answer, resulted in students being able to do well in the course without having any real understanding of the material. If you copied down the correct answers, you could do well.

While Molly saw the emphasis on one right answer as making success in math class easier, Ryan grew frustrated with the lack of qualitative feedback she received from her math teachers for whom answers were marked either right or wrong. She reflects on the last math class she took in college, which was such a negative experience that it discouraged her from taking more.

> She would just put a big red mark through it and just write no and that was it, no solution on the other side. That was it. That was your paper. A big no exclamation point, so you know you got it wrong. Where you messed up, that's for you to figure out, but you got it wrong.

Katelyn attempts to explain the difference between math and other subjects and the emphasis on right and wrong answers.

> In English, at least for the most part, even though there are rules, grammar, spelling, things like that, you're still often asked for your opinion and your opinion can never be wrong, so long as you can structure this, and your bibliography is that. Whereas in math, there might be different ways to get to it, but there's only one right answer, really. So even if someone isn't thrilled about English, they could probably… fudge it a little better in English than they could at math.

Finally, related to this issue of rule-following and emphasis on correct answers, homework played a central role in these participants' mathematical experiences. For example, Amala recalls spending a great deal of time during each class period going over last night's homework, and working on that night's homework assignment. She explained that her teacher would "go over each question on homework in class before we handed it in." Going over homework answers in class means that teachers don't get to see the students' original work, and that the teacher usually controls the learning process. Instead of being an intellectual exercise, homework becomes an exercise in obedience.

As discussed previously, in these classrooms the teachers were viewed as the mathematical authority. They are presumed to possess great mathematical knowledge and thus their students would usually unquestioningly obey their demands. Ryan illustrates how those teacher-directed lessons impacted her role in the class.

> I saw things, but I was just hesitant and I didn't want to say it, because I thought I'd get the wrong answer. I don't want to be like the one raising my hand in the class and yell out some bogus answer and everybody goes like, what the hell was that girl thinking in the back?

She explained later that she willingly spoke up in her other classes, but in math class, she was less sure of herself. She also explained that the nature of math class was that there was a right and a wrong answer, whereas in other subjects, there was room for personal opinions and "grey areas." Casey also made similar comments about this issue of right and wrong, or more than one way to solve a problem. She contrasts her experience with one teacher who insisted there was one "right" way to solve any given problem, with another teacher who encouraged finding multiple solutions to a problem.

> Even though I was doing the right thing, she was just like, no, I don't like the way you did this. So I wouldn't show my work. I wouldn't like get up in front of the class and do anything. Whereas, with my nicer teacher, I was like, yeah, I can

> show you how to do this, or this is how I did it. And she was like, oh yeah, there's like a zillion different ways to do it, there's no one right way. The other teacher thought it was just her way that was right. So, yeah, I guess it was just that, that I felt comfortable doing it. I liked the class and I understood it and I knew that even if I made a mistake, I wasn't going to get yelled at. I liked that part, and then, and because of that, after that first semester with the really mean teacher who like, you know, made me feel, I lost my confidence there for sure.

In situations where strict obedience is required, this results in student dependency, a lack of assertiveness, and a loss of opportunities for individuality or creativity. Students who are taught in such an environment may lack persistence, or innovative capacity. In other words, they may have difficulty adapting to new situations, solving novel problems, or thinking for themselves. This is precisely one of the criticisms participants had of their mathematical experiences. They argued that their math classes were impersonal situations where individuals were treated exactly the same, and there was virtually no opportunity to express one's individuality. Rachel expands on this idea of content being "personal" or "impersonal," by contrasting her math experiences with that of her English classes.

> I very much remember in my senior AP English class, there were so many more projects that we got to work on and things that we kind of got to put our touch on. And, I vividly remember when we read Canterbury Tales. We got to do all this really great stuff and we got to reenact things, and write our own versions and change things and we just got to be, a lot more creative and add our personal touch to things. And I think that's why I might have enjoyed those classes more.

Clearly, she is protesting the fact that math class offered very few opportunities for her to infuse her own personal interests and ideas into the learning process. In some ways she is resisting the formulaic and pre-determined nature of mathematics. She emphasizes the fact that in her English class she was able to come up with her *own* versions and *change* things, which speaks to perceived lack of agency in her math classes. She seems to be suggesting that math is impersonal because it does not require creativity, and she is not alone. Several other participants also perceived mathematics as non-creative (see Appendix A).

> I think it was something that never really interested me. Now looking back, it's kind of apparent, especially the career path I've decided to take, I'm much more of a creative person than I am a mathematical number cruncher (Rachel).

Rachel clearly sees math and creativity as dichotomous and incompatible. She also implies that only a certain type of person, a "mathematical number cruncher," would like math. This idea of a "number cruncher" reflects her limited view of what math is, and what mathematicians do. A "number cruncher" performs a series of computations, usually with a calculator, similar to the work of a tax accountant. Her binary description also suggests that people who do math do not have a desire to be creative, or maybe don't have the ability or inclination for creativity. Creativity is seen as being more challenging than just being a "number cruncher," because number crunching is procedural, tedious, impersonal, and unimaginative. In her mind, math requires obedience, while creativity requires originality, resourcefulness and imagination.

Due to the emphasis on obedience in math class, most of the participants in this study were able to earn high grades in those classes. However, despite their relative success in math class, these women were very aware of their lack of conceptual understanding of what they were learning. As the research suggests, these women's disinterest in mathematics developed independently of their achievement in mathematics (Catsambis, 1994; Dick & Rallis, 1991; Boaler, 1997). In fact, many of the participants discuss the fact that they disliked math class even though they were earning good grades in the subject and attributed this dislike to the fact that they did not understand the material (see Appendix A). According to Catherine, it is entirely possible, if not common, to do well in math, but not really understand it.

> You can go through high school and you can do it and you can pass it but you can never really get it. I mean, I feel like I have a ton of friends who just say that they never really got math. And you know, of course, they passed, and made it through high school and college and all that but, it's just this like weird thing that all these people never really click with.

Grace, too, uses some of the same language to describe her experience when she says, "It's so funny, it didn't, it's like I went through it, I passed, but some things were definitely not clicking." Other participants seemed to hate math because it was so easy for them. For example, when Rachel recalls her high school math experience, she explains "It's very odd, I'm not a huge fan of math. I never have been. I did great in classes, I could take math courses but it just wasn't anything that really pushed me."Casey also had a similar experience. "I just felt like I, I guess it was frustrating because when I was younger I hated math. I really just hated it but I always got hundreds."

Based on several participants' comments, it appears that one of the things that made math class both boring and easy was that it required a great deal of regurgitation or following directions. Rachel uses the analogy of a production line to illustrate her point:

> It was easy because you were just going through the motions and following the rules. Like working on a production line. It was tedious at times, but not difficult.

While it may seem that such an "easy" class would instill mathematical confidence, in actuality, the opposite occurred. For example, Ryan exposes her lack of mathematical confidence, when discussing how she put off meeting her college math requirement until the spring of her senior year.

> I was really scared to go take that class, I guess, because in my mind, I hadn't done any real math. But, that's not true, the bio professors would think otherwise. We did stuff with graphs and everything but to me that wasn't real math. But, yeah, I remember being anxious to take it.

It is significant that she feels she hadn't done "any real math" leading up to taking that course. She had taken a statistics course, and taken several biology and chemistry classes, but somehow she still felt insecure and anxious about her own math ability. Teacher directed lessons and rote practicing of procedures left participants feeling inadequate and lacking confidence in their abilities. In many ways, these participants recognized that the math they were doing was not "real math" in the sense that it required very little mathematical understanding. They understood that if put into an authentic problem solving situation, they have very few problem-solving strategies.

Ultimately, the emphasis on obedience in mathematics leads to a general disinterest in mathematics, an overall lack of mathematical confidence, and beliefs that mathematics is a rigid, anti-intellectual and non-creative field of study.

Unconnected

In addition to describing their math experiences as an anti-intellectual exercise in obedience and rule-following, participants also frequently expressed their frustration with the lack of connection in mathematics. These desired connections ranged widely from personal connections, connections to the real world, connections to previous math learned, connections to other subjects, and connections with others while doing mathematics.

As discussed previously, the participants not only disagreed with the procedural nature of their mathematical experiences, but also desired opportunities for connected knowing. This type of knowing can only occur when individuals are given the opportunity to learn by doing, communicate and collaborate with others, and to see the ways the math they are learning is connected to themselves, other mathematics topics, and the world around them.

In particular, several participants were frustrated that explicit connections were not made between new math topics and earlier math concepts learned (see Appendix A). For example, Grace explains how even though math is cumulative, each unit of study was seemingly separate to her.

> So many new topics, I mean it never stayed the same. Even though it's building, I mean, like, geometry from algebra to calculus, even though it was building, everything just almost seemed completely different at first.

This perception, that math topics were introduced in a successive fashion as seemingly unrelated concepts or processes was common among all of the participants. Ryan recalls that "there was no, there was rarely any background information", and Grace uses the example of being introduced to f(x) to illustrate the lack of connection made between new and old material.

> And definitely it wasn't a focus on learning to do things different ways. It was this is how the book says to do it, you're going to do it the way the book says. Sometimes you're wondering why your brain can't wrap, like y =mx+b, and then all of a sudden there's f(x) and you're like, no real chance to say, oh it's the same thing because you have to follow the set guideline and you have to finish. They don't take the time to just say it's just the same thing, they're just writing it in a different way (laughs).

In addition to the perceived disconnect between mathematical concepts, participants also struggled to see how what they were learning could be applied in the real world. This call for "real world application" of math was widespread (see Appendix

A). For example, Catherine suggests that students aren't taught the math that they actually need to know to be successful in the world.

> I remember thinking, well, I knew that it was used in science because we used it in science but I remember thinking, well, how do you balance a checkbook? I remember trying to think how adults used math and I remember thinking well, we're not learning any of that stuff.

She clearly sees how math is used in science, but expresses her frustration that she was never taught any of the relevant skills she needed in the real world.

Anyone who has ever been in a math class has heard the common question of "why do we need to learn this?" or "when am I ever going to use this?" Too often, math teachers do not have good answers to those questions. The participants in this study asked this question repeatedly as students, and continue to ask it today. Ryan explains how important it is for her to see how it is relevant to her life.

> At least when I learn something, if you can't teach me how it's relevant then it's almost like then I'll shut off because if it's not relevant then why are you even teaching it to me? If I can't take it out and somehow apply it to something that is happening to me on a daily basis or is going to happen to me one time in my life, then there's no point for me to struggle.

This dislike of mathematics permeated their schools. When I asked them to explain why they thought math was so devalued by their peers, participants suggested that they way it was taught made math seem irrelevant. According to Katelyn, the math is taught as something you will never need to use again.

> Because I don't think we put the same focus on math that we do on English. And I think that not only is it a widely held belief among students, I don't think people's parents or even their teachers really do a whole lot to change the conception of this is just something that you need to learn in school to understand. And you'll never use it again unless… So to be good at something like that, and to pursue something like that, is something, again, innate inside you. And it's worth it for you to take it those next levels. It's not worth it, or deemed worth it for other people.

Many other participants echoed her response. Casey discusses her extreme distaste for geometry, and attempts to explain why teaching the real world applications of mathematics were so important to her.

> For me, so it doesn't feel like I am doing something useless, like just for class. Geometry is the best example. I still have not used it. I know other people use it at pool, but I don't think so because I am not very good at pool so (laughs). All those proof things, I just don't see it in everyday life and I don't see what the point is. And I don't see anyone using it beyond geometry class, so you are only going to use it to get you to the next level. And that frustrates me. Why are we doing this?

Rachel similarly describes why learning mathematics seemed pointless.

> It was never something that was presented in an applicable way to using outside in life. It was here is your textbook, we're going to go through these three example problems, do your homework, turn it in tomorrow. It was never presented in a way of how you could use it beyond that. There were never any hands on activities, there was never anything to challenge you, there was never anything to, you know, let's put this in a real life situation of how you could use this information, these learning tools. So, it was just never really presented in that way. So, it was something that was, I feel like growing up math was something that was presented in a way to me in a way that was, I don't want to say boring, or, there was just nothing else that you could do with it, if that makes any sense. It was, you need to know how to do these things but you're never going to be able to apply them to real life or do anything with them, it's just that we have to teach them to you. So, do these problems and move on (laughs).

Molly, too, suggests that it was only when she was solving word problems that she was able to see how the math she was learning related to the real world.

> So, I remember liking when I had word problems because I could relate it to the real world but for me, I didn't really didn't know how math applied to things.

One of the final questions asked in the third interview was what advice participants would give math teachers about how to make learning math better for all students. The participants' responses were stunning in their similarity. All nine participants recommended that more real world applications be included in math class.

For example, Grace offers some concrete examples of what she sees as important pedagogical practices.

> I would say they have to gear math more towards real world concepts. You have to actually go out and do projects from the very beginning. Almost like build little engineers from day one. Because the way that they do math, the way it's presented, it's like oh, this is something that I'll never ever have to do in my real life. And that's definitely not the case. Instead, I would get up more, walk around, do projects. Not just sitting at your desk. I think that makes it boring and you can never see how math is applied in the real world… I think math is so much more interesting than the way math teachers present it. There's no energy, no joy, no zeal.

While Grace focused more on the actual teaching practices that she felt should be used in the classroom, Rachel suggested that teachers get to know their students' career interests, and find ways to show them how math will be relevant in those careers.

> I would have been able to enjoy math just so much more if somebody had just taken the time more in my later years of high school to say, you know, this isn't just something that you need to retain for now. This is how you can use it later. Or, what do you want to do as a career, Rachel? Oh, ok, you want to go into graphic design. You have to understand these basic principles to be able to do that. There was no tying A to B. There was no teacher projection on how any of that could be used or resourceful down the road. If you asked me right now, how could you utilize anything that you learned in algebra, my reaction would be, I don't use any type, you know, anything. Because the connection was never made for me.

Separate knowing predominates traditional mathematics education today. These women sought connection between mathematical topics, and applications of the math they were learning to the world around them. It should come as no surprise that when denied opportunities for connected knowing, these participants perceived mathematics as useless (see Appendix A). Only two participants, both currently working in math and science careers, see mathematics as important in their daily lives and in their careers. Harper, in her work as a physicist, "wanted to use math for something… as a tool."

Grace's perception of mathematics is quite similar. She makes an argument that in order to be a successful citizen, people need a basic level of mathematical literacy.

> I say it depends on what it is that you want to do. If you want to do a regular job that requires, I mean, I think they need basic maths for everyday living. For, how do you know that your mortgage calculations are right? I went with my mom to buy a car and they hate me because I went through the whole document, found errors, oh, the next time you came, it would have been fine, they even called another place to warn them about me because I'm going through to make sure that everything is calculated. And I'm like, wow, they do that and I know math, what about the other people that don't know math. I think math is good for everyday, even just going to the store and saying 10%, 50% off, you can calculate it in your head as opposed to going, ah… I think math is the foundation of everything, but I'm a math kind of girl, so…

However, these two participants were alone in their opinions about the usefulness of mathematics. The other participants revealed their perception that only people in certain careers "need math" and that they saw their mathematics education as useless. Ryan explains that many students at her high school did not take precalculus because it wasn't included on the state standardized tests.

> And then, you know, as the year kind of went on, because it was optional, you didn't need to take it, nobody needed precalculus, people could not take it and be fine. You needed up to like ah, they taught according to the Regents, precalculus was not on the Regents. So you were taking it just to take it.

Her statement that "you were taking it just to take it" makes it seem like taking precalculus was more of a whim, and certainly not expected or required. In fact, she argued that you could "not take it and be fine." It clearly was not a subject that she and her school deemed necessary for success in life. Catherine also struggled to see the relevance of the math she was learning in school.

> I guess with the math I remember thinking a lot of the time, I just don't understand why I have to know this. You know, like that whole thing. And, I just remember thinking, I'm never going to use this and I guess whatever kids think about math.

While she is referring to her own issues with math, she mentions “that whole thing” which implies that it is a common discourse. Not being provided with reasons why she needs to learn it, she doesn’t try as hard.

As the participants continued to provide details of their mathematics experiences, it was clear that they perceived math class as an obligation, like household chores, that needed to be gotten through quickly and which had little meaning (see Appendix A). Rachel saw math knowledge as a requirement for promotion to the next grade level, and nothing more.

> Again, in school, all growing up, I just always remember math as something that they had to teach us, that we had to understand to be able to get to the next grade. That you had to be able to do, you know, these three things and then you could go up to the next grade, it was just never anything that was presented in a way that you need it in any real life situation… It was just something that I had to take. It was something that I had to do… And, again, it might not have been so much as something of a statement of I don’t like it, it was just more of a it’s math. I’m going to go to class, I’m going to do my math homework, and that’s going to be the end of it. It was just, there was no real reason to like it or enjoy it because it was never presented in a way that there’d be any reason to.

Molly recalls just wanting “to get that class over with” and says that math was always “something that I knew that I had to do, but, and I didn’t necessarily dislike but I just, I didn’t really like it a lot.” Katelyn explains that until she attended the SummerMath program, she thought “oh it’s my math requirement, let’s get that out of the way.” She also believed that “other people who did well at it probably still saw it as a requirement, something to get through.” Therefore, in her mind, even students who excelled at math still saw it as a something they had to do, rather than something that was meaningful or interesting. Catherine suggests that one of the reasons that she didn’t excel in mathematics was because she only did the bare minimum to pass her math classes. She says, “so, instead of, you know which I regret now, instead of trying hard and making it something that maybe I was good at, I was kind of, I put in as much effort as I needed to and did fine but never did great at it, I guess."

This putting in only as much effort as was necessary to pass is a common story. It is an obligation, a hoop to jump through, not a learning experience. The students see little or no value in trying to learn the material, or see that that knowledge will be necessarily later in their lives. They merely see it as something to hurry up and get it over with, so they won't ever have to do it again. It isn't horrible, but it isn't worth their time either. Teaching and learning math are perceived as obligations. The teachers just "have to teach them to you", which implies that they don't really want to, or are only doing it because someone else is telling them they should. Math has no implicit purpose or use, it is just something you have to go through.

As participants discussed what influenced their decision to select a major, they described introductory courses that exposed them to the opportunities available in that particular field. For example, Rachel decided she wanted to major in mass communications after taking an introduction to publication and design course.

> It was something I was interested in and I had already had one course and I was like, I'm getting my feet wet and so that was first course that I took where I could kind of apply this whole interest that I had with being able to design things on the screen and be creative and create things. It was just really an eye opening experience as to what the next 3 1/2 years of school could be for me and what the world could offer me afterwards… She presented the world of communication and how many possibilities there were and all of the things that we could do and things that we could learn.

Her first course in the communications department laid out all of the wonderful possibilities, and the many ways that communications could be used. It got her excited about the field and helped her to begin to imagine what a career in communications could look like. And more than that, it allowed her to see the variety of careers available, not just one path to follow. She could see how her own interests could be pursued within that field. This is a dramatic contrast to calculus, which is the first math course taken by most college freshman. It is extremely rare in those classes to discuss the opportunities available to math majors. Perhaps at math major orientations these things might be discussed, but in order to attend one of those meetings, one must already have an interest in mathematics.

As a result of taking only calculus as their introduction to the mathematics major, many students select out, or "move on." Even Harper, who did take several upper level math courses to fulfill her chemistry major requirements, argues that she didn't see the ways math could be applied in a career.

> Yeah, no, not really. Again, probably if I had taken more classes, I probably would have seen the applications later, but I didn't. But, they had problems where they were trying to apply it, apply the technique to a problem, but you get a lot more of those in science classes anyway.

She suggests that perhaps in later math classes she would have seen the application. But how many classes should a student have to take before they begin to see the career potential of a major? Casey argues that more discussion of career applications of mathematics needs to be introduced early on.

> I think in high school it's probably really important to show what kind of job, just somewhere where every single topic is being used. I look back now, and I think they could have done that in geometry and I would have appreciated it more. I might not have liked it, but I would have been like, well, it's for somebody, not for me, but for somebody.

Overall, this lack of connected teaching and learning leads to a limited understanding of the usefulness of mathematics in everyday life. This perception of uselessness encouraged participants to see math as an obligation, and thus only put limited effort into their mathematics learning.

Unsupported

Participants begin to paint a picture of their mathematics classrooms, where obedience was emphasized and opportunities for connected knowing were limited. In addition, participants explained that they felt unsupported in those classrooms, attributed primarily to their teachers' lack of pedagogical content knowledge. As they progressed through school, their individual needs were scarcely met, leading to boredom, frustration, and alienation.

While for each participant, boredom arose for different reasons and under different circumstances, all of them described math class as boring at some point in the three interviews (see Appendix A). For some participants, math was easy for them, and their boredom arose from a lack of challenge. As Catherine describes her elementary math experiences she makes a connection between the ability to go at one's own pace and not being bored. "We went at our own pace so we were never bored because we could just keep going up." She goes on to describe how in high school math classes, she felt the teacher spent most of the time assisting slower students, so she grew very bored. In a similar way, Katelyn complained of boredom, resulting from the fact that she didn't understand the material and felt she didn't have enough time to digest and learn the material.

Participants suggested that more flexibility needs to be built into math classes, so if a particular student or group of students need additional time to explore a topic, that can happen (see Appendix A). Harper describes an experience where the math she learned in elementary school was,

> … just out of a workbook. And they would tell you where to start in the workbook, and tell you to, ok do this one today, do that one tomorrow. And if you finished it early, then you could get started on the next one. So people would just go at their own pace through the work.

What is surprising, however, is how fondly she remembers that experience. She explained that while she didn't enjoy the solitary nature of the work, she did enjoy being able to work at her own pace. She was a student who always excelled at mathematics, and in her previous math classes, had spent a great deal of time waiting for her classmates to catch up.

This relationship between pacing and boredom is significant. Individuals get bored when something doesn't interest them, when they don't understand it, or when the material is repetitive. Catherine, too, recalled the benefits of a "loosely structured" Montessori classroom where students could go "at their own pace." As she continued to contrast her Montessori classroom with her traditional high school math classes, she chose to describe the physical arrangement of the furniture, highlighting "rigid desks and rows" in the traditional classroom. Her words evoked the feeling of constraint and militarism. She also talked about "everybody doing the same thing all at the same time like soldiers marching." She described the problematic nature of a synchronized classroom, where all students are working on the same problem at the same time. In those types of environments, if one person is "out of synch" they stand out dramatically. This could be good for identifying students who need extra help, or bad, because it stigmatizes students or encourages them to hurry, rather than to understand the material.

Since most high school classes today are still taught in the synchronous nature that Catherine described, many students needs continue to be unmet. Participants that represent both ends of the math ability spectrum complained that their math classes did not address their individual needs. Rachel, who was a strong math student, expresses her frustration at not being challenged in class.

> And at my high school, if I got a B on an Algebra test I got upset, that's not good enough, I can do better than that, but in the eyes of my teacher, I was one of three people who got Bs and everybody else made Ds so they're going to focus on them, that's the problem, we're not the problem. We're doing fine, we're doing ok, if that makes any sense.

Catherine, being an "average" student, also had complaints of not getting enough attention from her math teachers.

> But, if you wanted help, there were like 15 other people who maybe needed help more than you, and I just remember that it was kind of harder to be in the middle. I wasn't at the bottom, but I wasn't at the top, and you really had to work to get the personal attention, you had to stay after school or come in early, or stuff like that which isn't always easy as a middle schooler.

Katelyn, a struggling math student, felt that math class went far too fast, and that she never had time to digest the material she was learning before a new topic was introduced the following day. She argued that because of the way her math classes were structured, predominantly relying on lecture, there was never time in class for her teachers to give her extra help. She discussed the fact that she felt reluctant to ask questions in class because she knew it would "slow down the rest of the class, who already knew the material."

While Katelyn's struggles in math class resulted in a failing grade and the need to repeat the course in the summer, Ryan's struggles were not remediated. Instead, she explained that she "went to those schools where it was like, oh you're such a nice kid, so let's just move you up." All four girls tell similar stories of feeling invisible in their math classes and not getting enough personal attention. Therefore, this suggests that pacing and individualized instruction are important for maintaining student interest and engagement in mathematics.

This lack of differentiated instruction often left participants feeling frustrated and alienated. In fact, almost all participants recollected that math got increasingly more difficult over time (see Appendix A). For these participants, middle school appeared to be the time when mathematics became confusing and unenjoyable. Amala tells her story of declining interest in mathematics:

> You know, I don't know, when I was younger I remember being really into math. And I remember fourth grade was like knowing my multiplication tables like this and it did decrease, it did go down. In elementary school, I remember being really good in math. And as I got older, it didn't come as easily (Amala).

Amala's comments are particularly poignant, as she continued on to take AP Calculus her senior year. Her perception that she wasn't as good at mathematics is important. It is also significant that her dislike of mathematics was not due to her poor performance in those classes. She goes on to say,

> Yeah, I guess, as I got older I didn't enjoy it as much. I guess I enjoy it when I understand it (laughs) that sort of thing. I was really into multiplication tables in elementary, you could ask me something in math, and I knew it, and then I don't remember much about math in junior high, but in high school I started having to really work hard to get it.

In fact, she did quite well in all of her math classes. Instead, participants seem to attribute their decline in interest to the fact that they always had to "put more effort into math." Grace explains that "the other subjects just came a lot easier so I didn't have to put that much effort into them, as opposed to math, it was more like you had to be diligent." Many of the participants describe their math experience as "fine" up until a "certain point." Ryan illustrates this when she says, "I still like math but there is always that up until a certain point. If you get past precalculus then I have nothing to talk about anymore."

Again, perhaps the transition from a single elementary school teacher to 50 minute classes per day at the middle and high school level, may have contributed to these feelings of dislike of mathematics. This is a similar story for many participants, that they liked math until middle school. This could be because middle school is frequently when schools stop using manipulatives and emphasizing real world applications. Or, perhaps their disinterest is related to the fact that adolescence is when gender roles start to congeal and the expectations for boys and girls really start to diverge.

Several of the participants told stories of the wounds or long-lasting effects that a negative mathematics experience has had on them. For example, Katelyn explains that "In the in the 9th grade was geometry and that's where it lost me." She describes her experience with a teacher whom she felt didn't understand her, retaking and failing the course a second time during summer school, and just generally feeling defeated and alienated by math. She struggled to make the connections that were required in geometry, but suggested that it was never phrased in a way that allowed her to "follow" or "relate" to it. She also complained that the pace of the courses was too fast, and that the material was too disconnected from her own experiences.

Catherine's negative math experience occurred her freshman year in high school. Interestingly, in our first interview, Catherine retold the story of her high school math experiences with little drama or detail. She said she did "fine" in her classes, and had only vague memories of them. However, once she received her packet of documents from the SummerMath program, in which it said she had failed Algebra I, the feelings and memories came back immediately.

> Yeah, I don't know, it was actually, it was really kind of emotional to read all this, because I just, I don't know, I feel so, kind of bad that, I just remember it being just so hard now, and I remember, it's just crazy, it was really crazy to read.

In her application essay to the program, Catherine wrote "To me math is a constant source of aggravation, and headache.   For the life of me, I just can't understand it!" As she recalls that period in her life, the emotional residue of the experience is visible.

> The very first sentence is that it's a constant source of aggravation and headache. Which, when I look back before I read this, when looked back on my experiences in math it was a little more neutral of a memory than I guess it really was. It was always something that, and I spoke about it, how I kind of remembered distinctly that after I left my Montessori school was when it became at least somewhat of a struggle, but I had just completely forgotten how horrible it was for me. And, the fact that really started to jog my memory was talking about how I was a sophomore in a freshman math class, and how my friends got it and I didn't. And I just remember just how incredibly stupid I felt, and I was so embarrassed that I was in this freshman math class. And I don't know if I blocked the memory because it was painful, or what, but I had just completely forgotten about it.

Perhaps one of the reasons that the participants felt so unsupported and frustrated is because they usually worked independently in math class (see Appendix A). Catherine's story if fairly typical of all of the participants' experiences:

> Yeah, because I just remember in high school you weren't allowed to talk in class and when you were working on stuff in class you had to be quiet and do it yourself. I don't really know why that was their philosophy, because, and it wasn't in all my classes. I remember a lot of group work in economics and almost all of my other classes except for math. I just remember in our math classes it was be quiet and do this, if you have a question come talk to me, you know, the teacher, which just seems like a really flawed way to let kids do things.

Catherine's experiences directly contradict teaching recommendations made by the NCTM (2011):

> By working on problems with classmates, students also have opportunities to see the perspectives and methods of others. They can learn to understand and evaluate the thinking of others and to build on those ideas.

In fact, research suggests that girls and women prefer and are more successful in math classes which emphasize cooperative learning over independent work (Fennema and Leder, 1990). The results of the quantitative survey data also reveal the participants' preference for working collaboratively, with a mean response of 1.105 (with 1 = often) on the item "I would like to work with classmates on math problems." This is not surprising since, similar research has found that girls and women prefer connected knowing, which involves working and learning with others (Gilligan, 1982). Instead, participants like Molly recalled sitting in groups during high school math classes, but not really being encouraged or given a reason to collaborate.

> Yeah, we worked in groups of four. But we wouldn't really talk to each other. We'd just sit there and work by ourselves.

Molly suggested that one of the ways she might have been more successful in her college calculus class would have been "if it had been a smaller class and she could devote more one-on-one time or group time. We didn't work in groups." Perhaps if she had, she would have felt more supported and less alienated from mathematics as a field of study.

Similarly, one of the recommendations participants' made for improving mathematics instruction was to encourage teachers to make themselves more accessible and properly trained in the pedagogical content knowledge of the field. When asked what they thought their teachers should have done differently, several participants discussed making themselves more approachable (see Appendix A).

> Yeah, maybe encourage students to come and ask them questions or like discuss problems with them. I mean I guess that's more, I guess that applies to math too. That's how I feel about science classes is teachers should make themselves available. Because sometimes you just get the wrong idea from the lecture and if you go and talk it out with the teacher then it helps you understand it better (Harper).

Several participants shared stories of teachers who were unavailable outside of class or unapproachable in class. They also shared their reluctance to ask their teachers for help if the teacher didn't make them feel comfortable.

> Yeah, I know I did in calc, but I remember I wouldn't stick with it too long. I think maybe that's when I did start asking for help. See, if I felt comfortable with the teacher, I would ask. If I didn't like the teacher, I was kind of lost, but I wasn't going to go to them (Casey).

> I guess letting kids know that they can come in for help or offering the help, you know? There are some professors who are there just to teach class and they need the money for their research thing and so they are here to teach class to get that money. Where there are some teachers and professors who are really into making sure that their class understands. And you can tell, you can tell which kind of teacher you have. And I guess I'm not really a very aggressive person, so if I get that vibe from you that you are just here to teach me, whether I understand it or not, I'm not going to approach you. I'll try to do the best that I can on my own. So, I guess, something like that would help (Amala).

As participants were asked to describe a math teacher that they particularly liked from their past, many of them described teachers who were approachable. Katelyn explains why her math teacher was so pivotal in her success her senior year of high school.

> The teacher fantastic and always made herself available, like she had office hours posted even though she didn't have an office. You'd like show up at a classroom and she made herself so available. That helped.

Ryan focused on a teacher being non-evaluative and willing to help students learn.

> You know, if they're nice, if they're kind, if there's this welcoming kind of ask me whatever kind of question, no question is a stupid question, kind of mentality then I think all students will excel.

In addition to making themselves more approachable, argued that teachers who possessed adequate pedagogical content knowledge would have made them feel more supported (see Appendix A). The participants' comments reveal their frustration with their math teachers' inability to break down complex concepts, and to make the math accessible and fun for students. They astutely pointed out that while many of their math teachers were "very smart," and were very knowledgeable about mathematics, that did not translate into being able to teach it effectively.

> And my teacher, he was like, he knew his stuff, you know teachers who can really know their stuff but they can't teach? I guess it's like two different skills (Amala).

> I guess there were teachers who seemed like they were teachers first and mathematicians second. You know, because some of my teachers were definitely mathematicians first, and just happened to be teachers. I had two teachers who were like that and they were just so intelligent that I just felt like everything they said was so far above half the people in the class. And they just had a hard time translating that into talking to tenth graders. I just remember thinking this person has no concept that somebody might not be really good at math or somebody might not understand this right away. It was just harder for them to fathom (Catherine).

Katelyn explains how "rare" it is for a teacher to be extremely good at something and still be able to make it comprehensible to students.

> She was one of those very rare people who was so good at something but could come down to your level to explain it, whereas you know some people, they are so into something that they don't necessarily understand that you're not really following the words their using. Because to them it's as natural as breathing. Yeah, she was just so fantastic at explaining things.

In other words, most of her previous teachers did not possess that ability. She, like other participants, is pointing out perhaps one of the most critical areas for improvement in mathematics education.

Rachel also blames her frustration with mathematics on her teachers' inability to make material "relatable" to students.

R: And I think in our math classes, the teachers just couldn't think of any way to take what we needed to learn out of the textbook and put it in a different context for us to be more hands on and it be more relatable to what we needed to understand. So, I think, in our English classes and science courses and things like that it was just they made it more, I don't want to say hands on, more personal…

I: More personal.

R: Yeah, they made it more interesting, they made it more so that you wanted to care, that you wanted to be involved in it, if that makes any sense.

Clearly, being able to make math relatable to students is related to being able to help students make connections between the math they are learning and their own lives. Here Rachel is implying that math class was impersonal, where individual needs and interests were not taken into account. Each person is treated exactly the same and efficiency (and obedience) is the goal. In contrast, a "personal" experience feels as if someone is paying attention to the individual, her input is taken into account, the service is tailored to her, she is valued, and she is listened to. It is difficult to feel supported in a faceless crowd.

As discussed in Chapter 1, schools, and math classes in particular, employ surveillance practices to regulate and control student behavior. For these participants, math class was indeed a place where they felt that their performance was intentionally made public and where they were constantly watched and measured (see Appendix A). Those situations made participants feel extremely uncomfortable and anxious because their mistakes and failures were constantly made visible by certain teaching strategies. Several students discussed their reluctance to do "board work" in classrooms where teachers emphasized getting the right answer, as opposed to listening to their problem solving strategies and mathematical reasoning.

And I remember having people come up and put answers to the homework on the board whether we knew it or not and I didn't like that because if I didn't know an answer, I didn't want to go up there and have everyone know it that I didn't know it (Molly).

Another form of surveillance was making students "show their work" on homework and class work. Casey, in particular, resisted this practice, arguing that she could do it "in her head."

> Because another thing I didn't like about math was that I could do it in my head very well. And my teachers were always like show your work, show your work. And I was like a really shy little kid, and I would not talk back to my teacher or anything, but I used to go and have actual arguments. I did it, I know it, you can give me a problem and I will show you that I can do it, why are taking off 5 points because I'm not showing the work? It doesn't make any sense, I know it, I know how to do it! And I had some teachers who would grade my tests differently because they saw that I could do it, and they knew that I wasn't copying or anything.

When I asked her what she saw as the reason why teachers made her show her work, her response was limited to reasons of surveillance, rather than to achieve some educational goals.

> Just to see where you are in the class and I guess to see if you're actually doing the work, not just asking someone to help you. Because if you just have the answer, a lot of times it looks that way. I know I used to have one teacher who used to say that they want to see the work because they want to make sure you're not copying or something (Casey).

Another common form of surveillance in math classrooms that was discussed by several participants was making students grades on assessments public information. Casey retells an experience she had in math class, where the student who earned the highest grade always got their test back first, and the rest of the tests were handed out in descending order.

> I feel like it depended what subject it was. Like, there was a history class where I always got my test back first, and in that class it didn't seem to matter too much, no one seemed to say anything. But when it was math, I remember there was this girl who was like the smartest kid in the class and she always got hers back first, and it was like, you know, yeah her again, her again, her again. And at one point a guy got his back first and it was like this big victory like oh yeah he got his, he beat her. It's sad in both ways because she was crying after that. I just don't ever want to be in that position. I don't ever want to be the one crying, I don't ever want to be the one that everyone wants to beat. I don't ever want to be the one who got all of the attention. I didn't like attention. I was very shy. I knew in math, hopefully, I just want a 90 something, but don't want to be perfect, because I can't deal with getting my test back first.

She makes it fairly clear that getting tests back first in other subjects was no big deal. However, being someone who got the highest test score in math class was somehow significant and traumatic. She continues by describing the difficult experience her cousin had in school because she was singled out for her high grades in math.

> She always got her test back first, so everyone knew she got a hundred all the time, and she wore glasses, and you know, everyone thought she was a little nerd. And she would come home crying, and saying "I'm going to fail my tests because everyone thinks I'm so smart."

These pedagogical practices, which emphasize conformity and competition simultaneously were sources of stress and discomfort for the participants. The lack of support participants received in their math classes increasingly lead to feelings of frustration and a lack of understanding. When confronted with the fact that they did not possess a conceptual understanding of the material, and realizing there were few opportunities for them to work collaboratively or to get support in other ways, most participants distanced themselves from the field of mathematics. They began to perceive mathematics as a frustrating and independent endeavor, one that rarely provided opportunities for collaboration or joy.

Summary

Through analysis of the interviews, three primary themes emerged about the way mathematics was taught. Participants described their math experiences as emphasizing obedience, unconnected, and unsupported (see Appendix B for summary). Math was clearly seen as an independent endeavor and as a subject that participants do not view as socially beneficial. Participants felt that rule-following, memorization, and regurgitation play a large role in their mathematics instruction, and that emphasis was on finding one right answer using prescribed steps to solve a problem.

Based on these descriptions, it is unsurprising that participants found much of their mathematics education as unmemorable. They had rich memories of other school subjects, and frequently postulated that they “would have a lot more to say if we were talking about social studies or any other subject.” In struggling to recall these details, the participants were reflective about these holes in their recollections. In fact, when asked to choose some words to describe their mathematical experiences, several participants used words like “unmemorable” or “none.” Ryan argues that “it was really like nothing.” But, Rachel provides perhaps the most poignant example:

> I: When you reflect on your math experiences from kindergarten until now, what words would you use to describe them?
>
> R: Oh geez. I mean, immediate, off the top of my head, I would almost say that I have none. I mean, it’s so unmemorable. I, there’s nothing from kindergarten up, there’s nothing like math wise in my classes that horrendously, that stands out to me.

In addition, math teachers were criticized for being inaccessible and unapproachable, as well as for lacking the pedagogical content knowledge necessary for students to understand the material. Finally, participants explained how their introductory college-level math classes were often negative experiences and that they did not provide an opportunities to see the types of career possibilities that are available in the field.

These negative mathematics learning experiences discouraged participants, with the exception of Harper and Grace, from taking course beyond the required ones in both high school and college. For example, Ryan states with some satisfaction, “And I met my requirements and I left math for good.” Many participants expressed this same sentiment of finishing the obligation and never looking back, and never using that information again.

The way that mathematics is taught in schools will influence the way that students perceive their own math ability and the field of mathematics. For these participants, the lack of autonomy they experienced in math class lead to a perception of mathematics as anti-intellectual, uncreative, and impersonal. The unconnected way that mathematics was taught resulted in beliefs that learning mathematics is a useless and impractical endeavor. Finally, unsupportive mathematics classrooms left participants feeling alienated from mathematics and insecure about their mathematical abilities. In the following section, I will explore the ways that mathematics is currently practiced, by focusing primarily on the experiences of one woman who uses mathematics in her current career, and by examining how mathematics is used by the other participants in their daily lives.

Practiced

Of the participants interviewed, only Grace and Harper are currently working in a math or science related careers. While Harper is still enrolled in school, Grace is currently employed in an accounting position. Her story will be used here to illustrate two key themes that emerged from the data.

Being the Only

As I talked with both Grace and Harper about their experiences in math and science fields, they discussed the competitive nature of their work environments, as well as the lack of women in their departments. Grace explained that as an accounting major, she only had two female professors in six years. But, when asked if the gender of the of the professor or the gender breakdown of her classmates was more important, she said,

> Well, I mean it's your classmates that you're going to interact with, study with. And then it depends. If the professors weren't as nice as they were, maybe it would have meant more to me that they were all male for the most part, but because they were all so helpful, and would answer any of your questions, I mean if people are pretty nice and ok, I'm ok. It doesn't really doesn't have to be any male or female, it doesn't really matter, it depends more on how people act I think. But it is always nice to see female professors.

Before Grace declared her major in accounting, she was taking a large number of engineering courses. She was acutely aware that she was the only woman, and only black person in those classes. She had several negative experiences with both her peers and her professors.

> No, if I'm going to be completely honest, it was the worst experience I ever had. I was like the only girl in the class, they were all white males in the class. I would go in, some people would be like "oh, I hate Black History month, I should rip down every Black History month poster". It was the worst experience I ever had. And maybe that drove more anything why I just wanted to quit.

After graduation, Grace got a job at a prestigious accounting firm. She recalls that despite employing hundreds of auditors, there was only one other black woman who worked at the firm, and eight black people total. She eventually left that job because of the competitive nature of the firm.

> I think finally I just woke up one day and quit. I was just like, I'm not happy. I was thinking about, oh, if I just drive off the side of the road so that I get injured enough so that I don't have to go to work but not enough that I die… (laughs). So that day I went in and made up a story and quit. I said, no, if I'm thinking like that, then I need to get out of here.

In her new accounting job, she still struggles with the fact that she has very little interaction with other women or minorities in her daily work. She explains that the farther she gets in her career, the less she interacts with other women.

> Oh, even at [Accounting Firm 2] there are a lot of women, but who runs the show? I was in a steering committee meeting. I remember, I counted because there were 23 people in the meeting. 3 were women and I was one of them (laughs). There were two black people. And the rest were all, there was me, the one black woman, there were two white women, and all were men, old white men. And at [Accounting Firm 1], it's like I think the women do all the little work underneath and the men are up top. I think about it almost every day. Sometimes I think, I'm in these meetings, and I think, what am I doing here? I don't know, it's sad. I was talking to my mom and she was like, why do you feel like that? I'm like, sometimes I feel like I just don't belong here.

She explains that while she is treated well by her co-workers and supervisors, she still feels out of place. She said, "I mean, I'm normally like 20 years younger than the next person in the room. But, I think about that too. Age, color, gender, it's just like, I feel like an anomaly."

Despite her success in the field, she has a defeatist attitude about women's role in business, suggesting that "men are always going to be in charge." Perhaps because of this, Grace believes that she must be more qualified than her male colleagues to advance in her career.

> You gotta be as qualified as possible, be the best that you can be because that's the only way you're gonna get ahead. I'm not going to have someone who's going to be like, oh, your father works here, I'll give you a big job. Oh, your friend, or someone that's like you is gonna pull you up, so if I don't do it by myself, then I won't get to where I want to go in life. So I might as well think to myself, you better be stronger, you better be willing to put in more hours. Ready to get more qualifications, accreditations, because that's the only way that you're gonna succeed.

<u>Competition</u>

It is a taken-for-granted assumption that fields like business, science and mathematics are more competitive and less cooperative in practice. From Grace's comments, it is clear that she perceives accounting to be extremely competitive. In fact, it is one of the reasons she doesn't plan to stay in her current job, and is seeking other career options, such as teaching or owning her own business. She explains that in her job, people do work together on projects, but that such collegiality is precarious. She calls her co-workers "frenemies," because they are friendly to her on a regular basis, but when it comes to advancing one's career, her colleagues do not uphold those allegiances.

> You see all these people working together. And you see them together and they're like friends, but you know, at the drop of a hat, if they know that to bring you down they can get ahead, the majority of them are going to bring you down to get ahead. So it's like you're friends, but you're enemies.

She characterizes her work environment as "cut throat" and deeply resents the competitive nature of the job.

> I think that the work environment at work is cut throat. Sometimes at work I simply want to say, I just want to learn. I don't want to take over your job, I don't want to step on top of anyone to get ahead, and if I ask you for help or your knowledge in something, it's only because I want to learn.

Grace's complaints that the accounting world lacks a "critical mass" of women, and is a highly competitive and confrontational environment are consistent with other research that examines why women leave math and science careers. (Lecampagne, et al., 2007; Stage & Maple, 1996).

Real Life

One of the ways to examine how mathematics is used in real life is to listen to how participants describe how they see themselves using it. With the exception of Harper and Grace, none of these participants see themselves using math in any significant way in their daily lives (see Appendix A). When participants describe how they do use math, they are frequently limited to calculating the cost of things when purchasing items or leaving a tip. For example, Katelyn, a bartender, explains how she sees herself using math:

> Well, my day to day practical applications with it now are counting money at the bar, drink, making drinks by ounces, and doing liquor inventory.

Amala, too, doesn't see herself using much math in her life, despite the fact that she works in a doctor's office.

> We all use it to some extent, but I'm not too much into math. As far as my daily life now, I don't take math classes. You have math in learning chemistry and physics, but in terms of my daily life or my career, I wouldn't go into accounting or business or any of that sort of stuff. So I use it, you know, my bank account or money, simple math, day to day math, or counting the hours of the day. I guess that's how I think about numbers is time and money.

When I questioned the fact that she claims she doesn't use math in the doctor's office she replied:

> I do the QuickBooks, make statements, input when someone pays us or they owe us something. I've never even thought of it that way. Yeah I do the accounting. Because it's so simple to me, I think math is supposed to be hard.

With this comment, she is revealing her perception that for something to be considered mathematical it has to be difficult. Therefore, she doesn't see herself doing any math because none of what she does is difficult for her. Molly sees the math she does as limited to figuring out a tip. She explains, "Well, I don't really do it at all. Unless I'm calculating a tip or something like that." It is interesting to note that all nine participants mentioned calculating a service tip in their responses.

Ryan, shares a similar sentiment when she says, "The most math I do is when I purchase something. I'm not really doing anything you know, extravagant." She is currently applying to medical schools and does not see math as playing a major role in her future career as a physician. She explains, "I know you need to know a lot of math if you're giving anesthesia, but that is not what I am trying to do (laughs). So to what I know of, currently, there shouldn't be a lot of math." Her limited perception of the role math plays in medicine reflects her perception of what real math is and how it is practiced.

It was obvious from the participants' responses that they had a very limited view of mathematics and its applications. Katelyn, like some others, acknowledged that she uses it to help her siblings with their homework. It appears that these women see math as being either a school subject, or something you use to help you keep track of your money. In terms of their careers, only Harper and Grace really see themselves using math in their careers.

> Not, not, really, no. I mean, I guess, group rates and that sort of thing, but it's not really heavy duty on the, it's more like plugging it in and sending people their invoices and that sort of thing (Catherine).

> Not really, not too much. With the exception of balancing a checkbook, paying bills and all that kind of stuff. Obviously I use it for that. But, yeah, not really. Not in school, that's for sure (Casey).

> My immediate response would be really no. But, I think so much of that, I mean, I would say no I really don't use math in my job. I do use a lot of computer science knowledge and my web skills as far as html and Java goes, and things of that nature. But my immediate response to do I use math in my day to day career would be no. (Rachel)

In terms of how math is practiced, based on Grace's experience, it appears that the field of accounting is still dominated by men. There is also a high degree of competition within the profession, to which Grace adamantly opposes. Based on the responses of the other participants, they do not see themselves using or practicing mathematics in their careers or daily lives, with the exception of managing money or helping children with their homework. The participants' limited experiences with mathematics in school are reflected in their limited perception of how central mathematics is to their daily lives. According to them, they do not recognize the types of math that they use and see math as irrelevant and virtually absent from their day to day activities. This perception, that math isn't necessary for daily living, is one that persists in k-12 schooling, and will continue to persist until students are made to recognize the applications of mathematics in the real world.

Overall, these participants described mathematical experiences quite consistent with the mathematics discourse (D1) presented in Chapter 1. The women described learning environments where docility and obedience were valued over creativity or problem solving. Math was taught to them out of context and without any real world applications. They personally knew few, if any, mathematicians and therefore knew very little about the actual work of mathematicians. As a result, the majority of the participants felt alienated from mathematics and lack confidence in their own mathematical ability. The way math is taught and practiced will influence what people believe math is, what it is used for, and who should engage in it. The themes identified in the previous sections represent some of the dominant discourses that currently exist about mathematics. In the following section, I will discuss how those mathematics experiences led participants to believe that mathematical knowledge was not important for societal success.

Power Discourse

As discussed in Chapter 1, while there is a discourse that exists that says that math ability is rare, there is an opposing discourse that says that math ability is extremely valuable and important to society (D3 in Figure 4). That being said, there was very little evidence of this discourse in the participants' comments about their mathematics experiences. Amala was one of the only individuals who made reference to messages she has received about the lack of girls in math and science.

> You know, I know the whole thing about there aren't enough girls in math and science. I never felt like I got that message that if you were a girl you weren't supposed to do good in math. But I definitely noticed the trend. Why is it? Why am I not interested in math? I have no idea. I don't know, but it's disturbing.

Grace looked at the problem more broadly, echoing the power discourse and the call for more mathematicians. Passionately she exclaims, "I think there needs to be a lot more things geared towards math. I don't think there are enough people that do math related subjects." She has lots of experience tutoring, and has become aware of the general lack of mathematical literacy in the United States. She continues by saying,

> I think we need more engineers, we need more accountants, we need more math teachers, we need more physicists. We need more of those people. Especially in the U.S. I think that we're underrepresented and that needs to change.

Surprisingly, the only individuals that used the power discourse in their interviews were participants who are in math or science careers (see Appendix A). Those outside of those fields did not mention a need for more mathematicians or imply that math is a powerful skill to possess. Instead, they focused heavily on improving mathematics education so that it emphasized more real world applications, problem solving, and sense making.

Perhaps one of the reasons that Grace and Harper saw mathematical knowledge as powerful is because they were raised in families where mathematics was valued. Of the nine participants interviewed, only Molly, Harper, and Grace consider themselves to be from a "math family" (see Appendix A). While Molly has no intention of pursuing a math or science career, Harper is pursuing a doctorate in physics, and Grace is an accountant.

Both of Molly's parents are involved in math education at the college level. She recalls her parents sitting with her while she was doing her homework, and using manipulatives like M&Ms to "make it more fun." She also remembers that "they tried to explain how everything worked, not just the answer but how did you get to the answer, and then once you found out one way, how could you get to the answer another way? It kind of became annoying fast." This push from parents to understand and explain why a particular mathematical process works, and to problem solve, is not unique to Molly. Harper tells a similar story about her physicist parents.

> Whenever I had a problem, like a homework or just curious about something, it was really annoying to go ask my parents because they would always just ask a question back at me. And I was like, no I asked you, and I want you to answer me. And they would instead of asking the exact same question back at me, they would like bring it back a step and ask a simpler question and make me walk myself through finding the answer to it. Which was really annoying because sometimes you just want to know. But it's probably also a good thing for little kids to have to think things out for themselves, probably helps my problem solving skills and stuff.

Early on, both Molly and Harper received daily training in problem solving, asking and finding answers to questions, and thinking for themselves. When I asked Harper what she thought influenced her decision to enter a science career, she responded by saying the biggest influence was her parents.

> I guess being raised by engineers helps a lot when you're a woman. It helps you a lot to not be afraid of going into a math oriented career. You're like, well, my mom can do it. She asks me all these questions all the time, right?

The importance of a same-sex mentor is clear here. She sees her mom in that role, so she can then visualize herself in the same position. As Harper described what it was like to grow up in a family of physicists, she recalled attending "Take Your Daughter to Work Day."

> I think I went from the time I was four years old or three years old. I think it was just one day of the year though. And the only thing I really remember from it is like looking at my dad in bunny suit. You know those things, like when he's in the clean room, and he's have all the little particles so you have to go into an air lock and you have to put on a white plastic-y suit.

From those visits, Harper became very comfortable in that environment and gained insider knowledge about what careers in physics might be like. In addition to those yearly visits to both parents' workplaces, Harper learned about engineering from conversations at home.

> I guess at the dinner table they would talk a lot about whatever they were working on at work. They would talk, they usually didn't talk straight up science, they would just talk about working in industry and having to deal with different people.

She insists that her parents did not push her into a science career but feels that those dinner table discussions probably influenced her to "go in that direction." She suggests that having physicist for parents "probably just left the door open for me to do it. To just be comfortable with, women, or just people being good at math and science." In fact, when Harper was in second grade and was asked to draw a picture of herself in ten years, she drew a picture of herself being an engineer.

She, like Grace, acknowledged that coming from a family with a strong mathematics background definitely gave her advantages in school because her parents could help her with her math homework. Grace recounts how, because of early interventions by both her grandfather and her mother, she was accelerated for her age upon entering school. She explains, "I knew how to do my time tables from like four or five. So, because of that, I went to the talented and gifted program." Her mother always loved math, but had to leave college before earning her accounting degree because she had a child. She believes her grandfather was a major influence in her interest in mathematics because "he used reasoning for everything." She proudly remarks that she comes "from mathematics. My mom loves math, my dad likes math, all his brothers are engineers in Jamaica. My grandfather loved math." This mathematical ability and coming from a "math family" is a large part of Grace's identity. She recognized early on that being a black girl who was good at math made her different, and at times she was ridiculed for it. But, because of her strong family support and the messages she was receiving at home about the importance of mathematics, she saw her math ability as a strength and decided to pursue a career that applied math in some way.

Other participants had parents who sent more positive messages about the role of mathematics in the real world. For Ryan, her parents sent a clear message that math was important.

> At home I was always taught that math was something that was used throughout every discipline. So, to really get a good grasp on anything you had to know math and you had to be comfortable with it. Whether or not I was comfortable with it at that point was completely different and beside the point. I had to become comfortable with it. I also think that is why my parents put me in this program.

Her family valued math ability, because they saw it as the ultimate challenge. Math was hard, so if you could do it, you could do anything. Her family helped her to clearly see the connection between math and science, and valued math learning because it would open doors for her. That is a very different message than most of the participants received from their parents.

Overall, the power discourse was conspicuously absent from these participants' narratives. However, as discussed in the section above, the way math was taught to them influenced how they perceived mathematics and its social power. These findings suggest that coming from a "family of math," where math is valued and at least one member uses mathematics in their career, increases the likelihood that an individual will use the power discourse when talking about mathematics. More research is needed to learn from families of math about how encourage girls to enter math and science careers. In the following section, a seemingly contradictory discourse, which states that math ability is innate and extremely rare, will be examined.

Ability Discourse

Unlike the power discourse, there was a great deal of evidence for the predominance of the math ability discourse (D2 in Figure 4). The math ability discourse is directly related to the mathematics discourse, as who is considered mathematically able will be limited by what the nature of mathematics is considered to be. Decades of research on sex differences, coupled with media portrayals of men as more mathematically able than women, has resulted in a widespread belief that women are not good as good at mathematics. On many occasions, participants made reference to research studies that they had heard about reporting that boys have greater math ability than girls (see Appendix A). They also indicated their familiarity with the attrition of girls in math, along with the debate about innate mathematical ability. Even if participants do not believe in the ability discourse, its existence as a dominant discourse has framed how they think about and understand mathematics as a field.

For example, when talking about why there were so few girls in her upper level math classes, Casey reports, "I know they do all those studies and men and boys are statistically better at math and science and girls are better at history and English." Harper argues that her parents convinced her to attend SummerMath when she gave "the whole spiel about how between certain ages like, 12 and 15 or something, girls stop talking in their math classes and so that's the theory behind this program and you should really go and experience it." Catherine's parents also tried to encourage her to maintain her interest in math. She said,

> As I was getting noticeably less interested in it, because it was my parents idea to send me [to SummerMath], and I think it was them probably worrying that I was losing interest because of the studies they'd read about how girls specifically lose interest because of various things. And I think they wanted to make sure that I wasn't losing interest because I didn't have these opportunities put in front of me or because I was sitting in the back of the classroom not wanting to talk because there were boys around, or whatever the studies were talking about with girls and stuff.

Similarly, Harper discusses a friend she had in high school, who used the math ability discourse as her excuse for why she didn't do well in math:

> Because I know that some of my friends, when I was in middle school and high school, would tell me stories about, well, my mom's a psychiatrist and she says that brains are not set up, or female brains are not set up to do math, so that's why I'm bad at it. I think that was her excuse.

Catherine was familiar with the discourse on girls' math ability from her parents and from her own reading. In her first interview, she pondered whether or not those research studies gave her "permission" to do "that stereotypical thing." She explains, "And I know that, I've read a lot about the girls dropping to off at a certain age when it comes to math and I don't know if I did that stereotypical thing or what."

Katelyn admitted that for a long time, she viewed math ability as something that you are born with.

> Because I thought of it as a skill set, kind of like people who can sing really well in gospel choirs and such. Sure, another person could take voice lessons or those people do hone what they have but it's an innate ability that gets finely tuned. Whereas I personally, no amount of voice lessons are going to make anybody want to listen to me sing.

However, after attending the SummerMath program and using a reform-based curriculum in her high school, her beliefs in innate math ability have changed. Now, she proclaims, "I don't believe it's an innate ability anymore because my personal experience with having overcome it, given a better environment that worked better for me." In other words, until SummerMath she believed that her struggle with math was due to an innate lack of ability. However, given the right support and opportunities, she began to believe that anyone can learn and be successful in mathematics.

Other participants still seemed to subscribe to the belief that you either have a "math brain" or you don't. For example, Amala proclaims that she just doesn't "have the physics brain." And Harper, when explaining why her sister was so good at certain types of math problems while she was not, suggests that "her brain is kind of set up that way (laughs)." This is particularly interesting because early on in our conversation, Harper appeared to be rejecting that discourse of innate ability, but uses it here to explain her sister's ability.

Participants also recalled the types of messages their parents sent to them, through their actions and their words, about the importance of mathematics. Katelyn, Amala, and Casey distinctly remember their parents admitting that they "just weren't good at math." While they encouraged their children to be better at math than they were, there was a subtle message being sent about the innateness of math ability. Also, since their parents were functioning successfully in the world with a self proclaimed lack of math ability, it sent the message that math ability wasn't very important. In Katelyn's case, her mom sent the message that her lack of math ability was due to a lack of mathematical genes. According to Katelyn, her mom would say,

> Be glad you don't have your mother genes. And she seemed to constantly jokingly say that she was physically incapable of doing it, whereas even if I struggled I had the potential to do well at it.

These participants provide powerful evidence that they were susceptible to the dominant ability discourse. This discourse, which suggests that boys are better at math than girls and that math ability is rare also creates a perception that math ability is innate and unchangeable. When coupled with the mathematics discourse, which makes mathematics seem difficult and alienating, it isn't surprising that participants would view mathematics teachers as "special." Several participants discussed the fact that they assumed their math teachers must be "really smart" because they possess the skills that they see themselves lacking. With this perception, participants admitted to feeling intimidated by their math teachers, far more than they were intimidated by their other teachers. For example, Rachel revealed her perception that math teachers were somehow inherently smarter than teachers of other subjects, which are "easier to fake." Catherine also made the comparison between math and English, recognizing her perception of those who are good at math as smarter than those who are good at English. She states,

> Math definitely wasn't something that came easy to me, so I feel like anybody who can do it well is pretty smart. Whereas, English that sort of thing, was something that did come easily it didn't seem as amazing when other people could do it?

So, with the existing discourse that nobody is good at math, when someone does excel at the subject, they are deemed "different" or "smarter" than others. She describes feeling intimidated by her math teachers.

> It's just funny that something that is less approachable to me, is somehow, that someone who is intimidating to me is smart. When really, it probably takes a lot more intelligence to make the material more accessible.

This is a critical moment of self-reflection here. She is realizing that she thinks that people who intimidate her are smart. But she is also being critical of that action, acknowledging that that type of thinking is actually probably flawed. Like Catherine says, it probably takes a lot more intelligence to make someone feel at ease and make material accessible. This seems to be related to the societal devaluing of emotional intelligence or social intelligence (Gardner, 1993; Goleman, 1996). This devaluing of emotionality could be connected to the devaluing of femininity and care work in the United States. For example, studies have found that workers in jobs requiring care work have the lowest pay, even when their education and experience are comparable to workers in other jobs (Kilbourne et al., 1994). So, perhaps even with a care work profession such as education, a teacher that makes us feel comfortable and welcomed is viewed as more nurturing and more feminine, and therefore less worthy or intelligent. Because of the dominant belief that math ability is rare, students may be intimidated by teachers simply because of their math knowledge. This suggests that intimidation has nothing to do with what the teacher actually does, but is present when the student enters the room. Perhaps students keep their distance from math teachers as a result of their preconceptions, and this leaves them feeling less personal contact with their teachers.

It has been suggested that "girls assess their mathematical abilities lower than do boys with similar mathematical achievements" and "hold themselves to a higher standard than boys do in subjects like math, believing that they have to be exceptional to succeed in "male" fields" (AAUW, 2010, xv). Catherine, who was successful in most of the math classes that she took, provides a poignant example of this phenomenon. She has an interest in returning to school to become a high school math teacher, but quickly convinced herself that it would be far too difficult.

> I feel like math is like learning a language and that it probably pretty hard to go back and learn it this late in life. I mean, it's something I haven't worked at or thought of in probably 7 years.

She views mathematics as a foreign language that would be too difficult to go back and learn "this late in life." She is 26 years old and has only been out of college for 3 years.

Is this simply a case of internalizing the dominant math ability discourse and believing that boys are better at it than girls and that math ability is so rare that surely she doesn't possess it? Or, could it be possible that women like Catherine actually have a more accurate and realistic perception of their mathematical abilities than boys and men do? For, if women recognize their lack of conceptual understanding and assume that boys possess that conceptual understanding, it would be logical that they would perceive themselves as unqualified to enter mathematical careers.

Deeply connected with the dominant mathematics discourse, the math ability discourse spreads the message that math ability is extremely rare, that boys are better at it than girls, and that math ability is something innate and unchangeable. The participants in this study were clearly influenced by this discourse, as illustrated by its frequency in their narratives. In particular, these women viewed their math teachers as smarter than other teachers and themselves. Similarly, they had a tendency to underestimate their own math ability and to assume that they did not possess the skills necessary to be successful in a mathematics career. In the following section, we will explore how these ideas about mathematical ability contribute to and perpetuate a discourse of deviance.

Deviance Discourse

The fourth discourse that was evident in the participants' interviews was the deviance discourse (D4 in Figure 4). As discussed in Chapter 1, the deviance discourse refers to the societal message that mathematical ability is rare, and thus, a form of social deviance. In the earlier discussion of the mathematics discourse (D1 in Figure 4), participants' characterized mathematics learning as isolated, alienating and anti-intellectual. The traditional way that mathematics is taught creates an image of math that very few people would identify with. Similarly, the math ability discourse (D2 in Figure 4) sends the message that math ability is innate and few people possess it. Therefore, it is unsurprising that people who are good at or demonstrate an interest in mathematics might be perceived as strange or deviant. In addition, the virtual invisibility of mathematicians and mathematical work in our society contributes to a discourse of deviance.

Often, the way one talks about a topic for which she has little personal experience is influenced by the messages sent by her peers and family members. The overt and hidden messages she receives about mathematics from other important people in her life will influence the way she thinks and feels about the subject. When asked what messages that were sent to them from their peers about mathematics, the participants all, without hesitation, discussed how most kids said they hated math (see Appendix A). Grace asserts:

> Everyone I know hates math except for me… They just said it was too hard, I'll never use this, why do I have to learn math, I'll never use this in the real life. What does math have to do with the real life?

In the participants' experiences, being bad at mathematics was far more expected and accepted socially than being good at it. It was understood that most people are bad at math. Casey explains, "A lot of kids didn't like math, boys and girls. So I felt like it wasn't cool to like math." Other participants had similar experiences. Katelyn discussed how she was sent messages that math was not a priority and that it was ok not to excel at it. While she acknowledged that subjects like English and History were emphasized, she recalled:

> It just wasn't important to be good at math. If you knew you wanted to be an engineer, or biologist or whatever, then you damn sure better have done well in your math and science classes but other than that, no.

Amala attempts to explain why, in the United States, math ability is seen as so rare.

> I think it's because most people don't get it as easily. Most, I think the majority, most people grow up thinking math is hard. You know, most people don't get math. I think that's the common mentality. It's acceptable if you don't do well in math. You know? When you say I hate writing papers, I hate English, I'm not into that, I like math or science, it's, people don't really connect with that. I think it's more common and acceptable to be bad at math and then to not like it.

In fact, when I asked participants if they could recall any of their friends who really loved math or was really good at, they said "No, I really don't" (Rachel). Harper, too, discusses the fact that in the dominant culture, math is generally disliked. So, in her opinion, math teachers have a much harder job than everyone else.

> Like my, a friend of mine's wife is a math teacher, and man, she goes through so much crap. She works down in Oakland and she makes these 7th graders respect her and it's pretty difficult. And she makes them excited about math. I mean, if people are able to do that, I really admire them.

In other words, teachers who manage to make math interesting should be admired, because for the most part, it isn't taught that way or doesn't capture students' attention. She would not say this about other subjects.

Several participants referred to math as having a "reputation." Catherine explains how her colleagues responded when she told them she was participating in a math research study.

> I don't know, I think math has a reputation that maybe, I don't know if it is unfair to math or what, but I just feel like it just this thing that people who were all right at math talk about math in this way that is just, when I was telling the people in my office that I was doing this thing, they were all like "Oh god, math, no. What are you going to tell her?" And these are all people who are incredibly intelligent and older. I don't even know if they remember high school, much less how they actually felt about math. But it's just kind of this funny thing that we all talked about. But I imagine that some of the people in my office are actually quite good at math.

She recognizes that a discourse exists around mathematics that probably isn't even true. In other words, people say they aren't good at math, even though they probably are. She suggests that it is normal in the current social climate to say we dislike math. Rachel also makes a similar claim, but this time using the word "mystique."

> It's just got this mystique. I feel like a lot of people, both male and female from a young age are so intimidated by it. It is something that, you can go through high school and you can do it and you can pass it but you can never really get it. I mean, I feel like I have a ton of friends who just say that they never really got math.

This word "mystique" implies it that math is mysterious or unknowable, like a magician's magic. Things happen, but you don't really understand why they happen. And this mystery makes it intimidating. It seems like some big secret that people just can't understand. Molly explains how her parents recognized the bad reputation of mathematics and wanted to counteract it.

> So they wanted to, because it had such a bad stigma, like oh, math it's boring, math sucks, everyone's always like, oh I'm horrible at math, I don't like it. So they tried to get me to not think that way. And I don't think that way now. Even when people are like, oh I hate math, and then usually the thing they say after that is I'm not good at it. That's probably why they hate it.

In addition to suggesting that it was acceptable to be bad at mathematics, the participants also made persuasive arguments for why math knowledge is not socially rewarded or necessary to fit into the dominant culture. For example, Katelyn contrasts the everyday use of English knowledge with that of math knowledge.

> Because even if there's math stuff going on all around us, we don't notice it, we don't talk about it. And even if we do, we're not applying it to lessons we've learned. We're like oh, that's messed up, I dropped this thing in my cup and it overflowed. Nobody is going to go back and be like oh yeah, displacement, you know what I mean? It doesn't tie back into a discussion of the core subject. Whereas, if you're good at English or you enjoy reading or something, we use language, just plain and simple. So it already has the drop on math like that (laughs) you know? Spoken conversation kind of trumps it.

She passionately continues by saying,

> And think of how many times maybe that you've been on the T and someone has leaned over and been like I love that author. I've read this. Whereas I guess the only time I can imagine, again, if we were taking the T as an example, of anybody talking about math, would be Sudoku, and people saying oh, yeah, I couldn't finish that one today. But again, they wouldn't go back to any other discussion about math. It would be just like that puzzle thing.

She argues that because of "people's built in experiences with it" nobody would want to hear about what she was studying in math. She explains,

> When you go home, again, it's just an easier thing to engage people in. I read this really awesome thing today, let me read you sentence of it, instead of like I learned this really cool algorithm today, let me explain it to you.

As Molly tried to articulate her disinterest in mathematics, she contrasted the social nature of English class with her perception of math class as being more limited socially.

> I think I just liked the stories, and like writing stories, and I liked creating things that people could relate to when they read, or something like that. As opposed to math, I feel like is not really a subject where you can communicate and interact with people as much as more doing yourself. Which, I know you can, interact with people when you do math, but I like different kinds of interactions. For example, if I wrote a story about my life or something, somebody could probably find commonalities with their life and then we'd have something to discuss about it as opposed to checking whether or not we had the same answers to a math problem.

Her explanation reveals some of her perceptions about mathematics as a field. She sees math as something that you "do yourself" and doesn't see the potential for communication and interaction with other people, as she does in other subjects. This is surprising, considering that she has had many experiences where she had to communicate about mathematics as both a student and a teacher in the SummerMath program. Somehow those experiences were not enough to change her view of mathematics as a subject that can be used to communicate with others. She recognizes that students can interact in math, but she sees those interactions as limited to "checking" answers instead of "finding commonalities with their life." This perception reflects her limited understanding of what math is and how it is done.

While knowledge of English, history or science might be socially beneficial because it allows someone to engage in intelligent dinner conversations, math knowledge is not required in social settings. In fact, it is assumed few people have any math knowledge.

According to my participants, not only was math ability not socially beneficial, it could also be socially harmful. When a person challenged this dominant discourse and demonstrated an interest or aptitude in mathematics, they were often stigmatized as "nerdy" or "strange" (see Appendix A). Molly pointed out that you could be good at English without being classified as a "nerd" but you couldn't do the same in math. She said, "Because if you were good at math you were like a nerd, but being good at English you weren't. I mean there wasn't really, I don't remember them calling you anything if you were good at English." While in some instances being good at math might be useful for career advancement, for the most part, math ability was not seen as socially beneficial. As mentioned earlier, getting the highest score on a math test made students the target of ridicule, especially for girls, while in other subjects, being the best was “no big deal.”

Girls who did exceptionally well in math classes and “were really into it” definitely stood out because they were few in number. Grace, who was a “mathlete” in high school, made a point to tell me that she also played “regular” sports. She asserted her normalcy by saying “I wasn’t just a mathlete,” as if that was a bad thing to be. Later she confessed that being a mathlete is “something I never like to talk about. It’s so weird because I was so nerdy in high school. So geeky.” She also admitted that she did not tell her classmates that she attended the SummerMath program. She explains, “Everyone at school only knew me as that smart girl. I didn’t need to add to my reputation (laughs).”

Harper, who was also enrolled in the upper level math classes, was cast as the “nerd” by other girls in her school.

> Of course, the other girls who were in the other levels of math kind of look at you and they say, oh you’re the nerd, you’re in the upper level. So whatever, I got it. So yeah, there’s probably social stigma associated with being in the hard math class.

As Katelyn entered the SummerMath program, she imagined being surrounded by a bunch of “nerdy” and “boring” girls, because what “normal girl would choose to spend their summer doing math?” These distinctions between normal and deviant, nerdy and cool still pervade their adult lives. Amala describes an interaction with a peer, as she reveals how much she loves math and science.

> I actually had a conversation with someone recently where they were like you really like that stuff, huh? So, I’m trying to, I think it’s still around. I mean, it’s great to get good grades and have goals but if when you are really into math or really into science like I am, it is still considered weird.

It seems, according to her, that it is perfectly normal for girls to get good grades in math. What is abnormal, however, is “being really into math or science.” So, it isn’t necessarily weird for her to want to be a doctor because she wants to help people, but it is weird that she might want to be a doctor because she loves science. In fact, this comes out in a later interview, as she admits that people think she is “strange” for liking science, but that it would “surprise people even more if I just wanted to do research. Because it’s not people-centered.”

Here, the entanglement of gender roles, the math discourse, and the deviance discourse becomes apparent. Math is perceived as isolated and irrelevant. Women are taught to seek out care giving and people-centered positions. Math ability is seen as extremely rare in the dominant culture. Therefore, if a woman demonstrates strong math ability and a desire to pursue a mathematics career, this is viewed as deviant behavior.

Participants’ impressions of mathematicians reflect the deviant discourse of exceptionality or strangeness (see Appendix A). When asked what comes to mind when they hear mathematician, the participants responded with stereotypical responses of a nerdy, isolated, socially inept college professor. It is not surprising that they would envision a college professor, as those are usually the only mathematicians they’ve ever met. In fact, many of the participants seemed to use their college math professor as their prototype, essentially describing them in their response. For example, Catherine postulates that “I imagine they have really messy offices, scratch notes of problems everywhere, I don’t know. I think that is based off of the one math professor I had in college, his office.” Later she admits that she really has no idea what mathematicians do.

> I don't know. I imagine a lot of them are professors and they work on really complex math things. I don't know. I had a roommate who was a math major. She's not doing anything with math any more but, yeah, I'm not too sure. Something beyond me.

Rachel also struggled to answer the question, acknowledging her obvious lack of knowledge about mathematical careers.

> I don't have a clear picture of what they would do. I think that is something that I've always struggled with and maybe what lots of other people struggle with. Exactly what do mathematicians do?

As she reflected on the question, Rachel imagined mathematicians to be very "intellectual."

> A professor (laughs). That's my immediate thought, would be somebody who would be teaching math, if you are a mathematician. Very inflexible. Well, I mean again, I'm trying to be very honest, and like the first things that come to mind, and I think when I do hear mathematician I get this very intellectual professor, not nerdy, nerdy is not the right word, but very intellectual person, when I hear mathematician. I do, I see this very prestigious, intellectual person.

Identifying mathematicians as "intellectual" is indicative of the general perception of mathematics. This is directly related to the math ability discourse discussed in the previous section. If mathematics is perceived as extremely difficult and it is understood that most people are not good at it, it would make sense that someone who chooses it as a career would be seen as "very smart."

Katelyn was also frustrated by her lack of understanding about what mathematicians do. She realized that she could easily imagine what a writer, or historian, or scientist might do, but that she could not create a picture in her mind of what a mathematician might actually do. She reflects on her gap in knowledge, and attributes it to the invisibility of math in everyday life.

> Well, I think, again, both things being equal to someone, more people could name you a writer or a poet, hell like a dozen writers, a dozen poets, and they couldn't name you famous mathematicians. Or, you might know that so and so who wrote this book got an honorary doctorate from Harvard but you wouldn't know or you probably wouldn't know who the most famous German math guy was in the world teaching at MIT. You just wouldn't know. That kind of stuff doesn't really make the paper or come up in conversation. Whereas any kind of reading, even if we're not talking about poets, any kind of reading is usually more common in your day to day life than let's say, trigonometry.

Overall, this lack of understanding about the work of mathematicians is unsurprising. For, if the only mathematician that someone knows is a math professor that they disliked in college, they are going to have a very limited understanding of math careers. This is especially true when introductory college math courses do not discuss potential careers in mathematics. In many ways, math is invisible in daily life. Mathematicians are rarely seen doing their work, except in a classroom. It would make sense then, that perceptions of mathematicians would match images of college professors and that mathematicians are imagined as difficult to talk to and lacking in social skills. After all, the logic goes that if they are choosing to work in a career that is virtually invisible to the social world, they must not be very social people.

How math is talked about in society will inevitably influence people's perceptions of careers are available in mathematics. During our interviews, I asked participants to discuss what they saw as possible careers in mathematics. For the most part, they were unable to generate a list of possible careers beyond being a math teacher or professor like those described above (see Appendix A). For example, Rachel admits that she has a very limited view of math professions:

> Oh geez. That's a tough one. Because again, if somebody were to ask me that on the street, I think that my immediate responses would be things that I would have said in high school. You know, you teach math, you're a professor of math. I don't think I would have gone to some of the things that you really have to have heavy intensive math in, like careers in the science field or the medical field or things like that. Or being an architect, for example.

Casey's response practically echoes Rachel's when she discusses what she saw as potential math careers prior to attending the SummerMath program. Interestingly, she wanted to become an aeronautical engineer, but she did not perceive that as being a math career.

> C: Before I went to SummerMath? Oh. I don't think I thought that you could use math in anything except for being a math teacher. Honestly. My dad used to tell me that he used math everyday and that you have to be good at it. He dealt with a budget. I was like, that's numbers, you're adding and subtracting, maybe multiplying. And he was like, yeah, but that's every day. But that didn't cut it for me, so, yeah, I definitely didn't think we used it. Like I said with the engineering thing, I knew it was there, but I don't know.
>
> I: You didn't think of that as a math career?
>
> C: Yeah, I didn't. That's what it was. I guess I just saw it all as coming with the territory, but I didn't view it as math. I don't really know what I was thinking (laughs).

Casey was interested in engineering, excelled at mathematics, but still did not view engineering as a mathematical career. Her response reveals the very limited discourse that exists about what mathematics is and how it is defined. Both she and Rachel thought about math in the form of their math classes in high school, rather than being able to imagine the types of applications math could be used for. Those applications, like aeronautical engineering, were somehow classified as something else, because math, in their minds, was not practical or applied.

Even Grace, who started out an engineering major and then switched to accounting, chose those fields because she did not see math as a career-generating field.

> I think of every person that engineering was their first major, I think 9 times out of 10, their next major is going to be business. Because it's still on the math front, you can get a career, as opposed to math.

In other words, math was her primary interest, but she didn't see it as a possible career choice. So, she opted to major in something else that used math, but was not a math major.

It is clear from the participant's comments that they see the link between mathematics and science. What is also apparent, however, is that they don't see a major in mathematics as leading to any career besides teaching. This limited view of careers in mathematics could be one reason why so few people decide to enter mathematics careers.

The deviance discourse has undeniably influenced how the women in this study perceive individuals who excel at mathematics and mathematics as a field of study. In many ways, these women were discouraged from expressing an interest in mathematics because doing so would have made them different from their peers. Individuals who did excel at mathematics were called names and socially marginalized for their abilities. However, it is unlikely that these social risks were the only reason these women did not choose mathematical careers. Instead, it is a complicated story. First, the traditional way that the participants learned mathematics limited their understanding of what mathematics is and who should do it. Second, there is clear evidence that math ability provides little, if any, social benefits in our society. Third, the invisibility of mathematical work and the negative portrayal of mathematicians in the media may discourage girls and women from pursuing those careers. Finally, insufficient math career information leads students to unaware of the potential careers in the field.

Sexuality Discourse

As discussed previously, the way math is talked about, practiced and taught will influence how people view the field and their place within it. Similarly, how sexuality is talked about and practiced will influence how girls perceive gender roles, and what they will see as possible and appropriate actions for themselves based on their gender (See D5 in Figure 4). In the following section, I will discuss the gendered messages received by participants, how participants see gender influencing their mathematics experiences, and how societal gender roles affect career interests.

Gender: A Discourse of Difference or Resistance?

Unsurprisingly, growing up as girls, these participants were sent many messages about expected behavior. These messages, sent both implicitly and explicitly, sustain a discourse about femininity and male superiority. For example, when Grace struggled with mathematics as a young girl, her mother's response was seemingly harsh.

> When I told her I didn't like math and I would cry, she would say, oh you're acting just like a girl, you're thinking like a girl. Because in Jamaica, back then, it was like most people that liked math back then, the guys liked math and the girls didn't, but she always wanted me to do well in math.

Her mother appears to be attempting to contradict the existing discourse that girls weren't good at or didn't like mathematics. However, her comment, by telling Grace not to act or think like a girl, reinforces the idea that the way men act and think is preferred or superior. In addition, she would not have felt the need to make such a statement if the discourse about girls and math wasn't so powerful.

Ryan grew frustrated with her parents differing expectations for her and her brother both behaviorally and academically.

> I could have been, you know, the world's top karate kid, and no, I would have had to have been indoors at night, and my brother could, you know, be on the prowl. And he was a trouble maker. I wasn't even a trouble maker, you know? But it was all written off because he was a boy.

Ryan was being sent the message that girls are more vulnerable and need protection, while boys are tough and can handle themselves. As Ryan got older, her parents also tried to let her know about the "realities" of being an African-American girl in the dominant culture. She explains that,

> When it came to school work and other work, I had to work twice as hard as my brother. And this is when she would tell me because I was a woman. So not only did I have the race going against me, but I also had that I was a woman going against me. So I was always going to have work harder than my brother.

Again, her parents, like Grace's, were attempting to contradict inequitable discourses that exist, and trying to arm their children with the skills, knowledge, and dispositions they would need to be successful in a world that discriminates against women. Catherine told similar stories about her father's passion for enrolling Catherine in every male-dominated activity he could find, including ice hockey and summer science programs. Early on, all three of these participants were made aware of the dominant gender discourse, and were encouraged to resist them.

Remembering the messages sent to her by her parents, when Ryan experienced gender or race discrimination, she was not afraid to speak up. She discusses returning to college for post-BA science coursework, and described it as being "thrown back into the real world." She reported that professors would call on the men in the class, while she sat with her hand raised and waving.   Finally, she took action.

> He kept calling on the white guy in the front row. And I stood up and said, excuse me, I have been raising my hand and I have a question. And that was when I realized, please, I don't want to have to get nasty.

The fact that that professor called on men more than women represents a powerful part of the discourse about gender in math and science. While Ryan had the skills and courage to voice her concerns, other women could easily take that professor's actions as proof that they do not belong in that field of study. Grace had a similar experience in her engineering coursework. However, her experience was so painful that she elected not to share it. Regardless, she made it clear that the "unwelcoming" attitude of the professor and her classmates was what made her change her major.

Catherine's parents, attuned to the trends of girls leaving mathematics, tried to encourage her to pursue activities that were traditionally male dominated.

> I played hockey when I was a kid and there were no other girls on the team. I think as a sociologist he was really sensitive to the fact that there were a lot of things that women typically didn't do, so he just tried to push me into anything he could possibly get me to do. He was always really explicit, and I remember kind of being like ugh, ok, I get it. But he would always ask me more specifically about how math was going and how science and was going, what we were doing in math, how do I like it, taking me to science museums, and always trying to get me interested in stuff like that.

As discussed above, while a dominant discourse about gender and sexuality exists, the women interviewed seem to have internalized the messages of resistance received from their parents. These participants seemed to enjoy actively challenging those gender stereotypes. For some of them, this took the shape of playing a traditionally male sport, or enrolling in a male dominated course. For others it meant consciously choosing to participate in activities that countered the gender norms, simply to disprove a stereotype. All of the women took pride in challenging these norms and surprising individuals by not fitting the stereotypes for their race and gender. Amala explains how, growing up, people were always shocked that she liked science and math.

> I kind of like that reaction that I get from people. Like, you can't confine me into a certain classification. I guess we all do it. You see someone and you think you know what they are and when you find out that that's not the case, it's surprising. So, I like that reaction. They're like "oh, you like math?" And I think that it happens even more now because I'm young, I'm a single mom, I'm Hispanic. And they're like, "Oh you're good at math? Oh, you're in school?" People don't expect that, so I like that reaction and I validate it with "Yes, I do like it."

Challenging those stereotypes and admitting that she likes math makes Amala stand out. But, in her case, she enjoys being different in that way and takes pride in it.

It is clear from these stories that the gendered messages that participants received simultaneously taught them to resist gender stereotypes and reinforced gender distinctions through a discourse of difference. In many of these examples, these women were encouraged to take on male attributes and male-dominated activities so they could be more successful in society. While this teaches girls and women that they shouldn't let gender stereotypes prevent them from pursuing their interests, it also reinforces patriarchal ideas that male ways of knowing and doing are superior and preferred in society.

Gender Blind

Despite the preponderance of messages of resistance they received, these women were surprisingly unaware of how gender played a role in their math experiences growing up. These participants were taught not to let gender roles limit their life choices. However, it appears that those messages also made participants blind to how gender does impact their everyday experiences. For example, when participants were asked how they saw gender influenced their math experiences growing up, all of them said it didn't impact their experience at all. In fact, most of them refused to acknowledge that gender played any role in their mathematics careers or their development of attitudes about math as a field.

They would readily acknowledge that many of their upper level math and science courses were dominated by men, or that most of their math teachers growing up were men, but they did not recognize that as influencing their disinterest or disconnection with math. Harper was sensitive to the fact that “the number of girls in class just sort of dropped off at the end of high school.” She said she felt ok about that, since there were always “enough” other girls in the class and she wasn’t the only one. Ryan explained that her physics class had “noticeably a lot more men” and that calculus “was full of them [men].” However, she insisted that the lack of women in those courses had no impact on her eventual dismissal of mathematics. In fact, she asserted that the boys’ domination was “not a problem.” Yet, in the final interview, she admitted that she felt her calculus teacher liked the boys better and treated them differently. She said, “I didn’t feel as welcomed, and it’s probably also why I chose Spellman. I didn’t feel as welcomed in that class as I did in my SummerMath program.” When I asked her why she thought there were so few girls in those classes, she said,

> It could have been a lot of reasons. People were having babies, you know, really crazy things. People were into trouble. I also think when you’re young there is, there is so many things you could be doing besides work.

Her limited ideas about why girls might reject mathematics is revealing of her lack of awareness about how gender might play a role in those types of decisions. She attributed some of the loss of girls to pregnancy, which is interesting. But, her other reasons do not explain why girls would opt out of math and boys wouldn’t. It is surprising that Ryan does not consider that the teacher’s favoring of boys might have played a role in girls’ lack of interest in math. However, this blindness or denial of how gender influences girls' math experiences was fairly typical.

Beyond acknowledging that boys outnumbered girls in upper level math classes, the participants did not recognize how that experience might have influenced their ideas about mathematics. When I asked Rachel, who grew up in the south, about the gendered messages she received as a child, at first she denied any. Perhaps her denial comes from the fact that she was only thinking about the messages her parents sent her as a child. For, later, she acknowledges that she received negative attention when she went against gendered expectations for girls in her small town.

> I do remember in high school catching a lot of flack from other people about wanting to get out and thinking that I was better and you know, I wanted to be a strong woman and I wanted to do all of these things. And it just wasn't what I was supposed to be doing. Most people that I went to high school with, you know, you graduated from high school, you got married, you had children. Which there is nothing wrong with that. But, the fact that I wanted to go on and do more was just not, it wasn't the norm, so I think there were some gender discriminative things in that aspect, but I don't remember it hindering me in anyway. I really, I don't want to say I shut it out, but in a way I did. I was so ready to move on that I probably did shut a lot of it out.

Other participants made similar claims that these gendered messages have not affected them and their career decisions. Amala attempts to explain her complex relationship with these gendered messages.

> I don't remember too many restrictive messages about what I couldn't, what I can or can't do because I'm a girl and what boys can and can't do. Well, growing up, I didn't have, it was just me and my sister, so in my family setting I didn't, there weren't any boys around to compare how boys are raised and how girls are raised, you know? So, I didn't experience that at home. In school, I think, sometimes I don't like to be told you're a girl you can't do this. That just makes me angry and I'll prove you wrong sort of thing. So I didn't really experience that classification of this is what girls do and this is what boys do. Yeah, I never felt intimidated by boys specifically, in any setting.

She seems to be contradicting herself. First she says she never heard restrictive gendered messages, but then she says she it makes her angry and she wants to prove them wrong. There is something about the sexuality discourse that prevents these women from acknowledging these gendered messages exist and that they impact their lives. She asserts that she never felt intimidated by boys and appears to be saying that she overcame these restrictive messages that she heard growing up. That may be true, but that doesn't mean those messages didn't influence her. Interestingly, the question asked was about gendered messages being sent by parents or peers, and she responded almost defensively by saying she wasn't intimidated by boys. She seems to feel the need to resist the dominant sexuality discourse within her interview.

In Grace's case, she felt that girls actually did better in math in high school than boys did. However, she was deeply troubled by the fact that in college, a clear reversal happened and girls dropped out of mathematics.

> There'd be like a handful of boys, they were exceptionally smart, granted, but for the most part, I think, throughout high school, girls did more math. Something happens, I think when they go to college and it's just like oh girls shouldn't do math. I don't know, I think something happens. Like it's more acceptable through high school, but not in college.

Perhaps girls' math ability is more acceptable in high school than in college because good grades in math are seen as a prerequisite for college acceptance, and it is expected that most girls will go to college. However, once they get there, math is not seen as a "normal" career path for women.

Gendered Careers

It should come as no surprise that career interests appear to be influenced by traditional societal gender roles. One of the themes that emerged from the interviews was the participants' absolute lack of knowledge about careers before and during their college years. As a result, they relied heavily on the feedback of parents and teachers to help them make decisions about appropriate career paths. This means that these women were highly susceptible to what others told them they should do and what their strengths are. Grace's journey provides an excellent example of how easily influenced students can be by someone's directive advice. In high school, Grace had a teacher tell her she was good at math and encouraged her to major in engineering. So, she did. Then, in her sophomore year of college, unhappy with engineering, a professor suggested that she switch to accounting because of her skill in the subject. She admits that she had "no direction, so I kind of just listened to what anyone would tell me, what advice, and that's how I ended up doing engineering first."

When Catherine decided to major in biology, she confessed that she had put "very little thought into it." She admitted that her father was very influential in encouraging her to pursue a science career, and that without his vote of confidence, she probably would not have tried the major. She ended up switching to a social work major later on in her college career, where she was eventually dismayed by the lack of practical information she had about careers. She explained that she was unaware that you are "not really a social worker with a bachelor's in social work" and didn't realize that until it was too late.

Many participants, including Catherine, when asked how they decided on their current career path, explained that they had a desire to "help people" (See Appendix A). All of the women described experiences they had doing volunteer work, and many of them had the desire to incorporate public service into their careers. This is consistent with other research which has found that women are more likely than men to prefer work that contributes to society (Eccles, 2006). Harper who is studying to become a material science engineer, explains her decision to get a doctoral degree, instead of going to work for a pharmaceutical company as a chemical engineer by saying, "I decided that I didn't want to go work for the man and make things that aren't really that useful, and are just out there for making money." Most of these women talk about making money as something that isn't important to them. And, in fact, many of them espouse the idea that having a career for the sole purpose of making money is not reputable. For all of these women, they have been socialized to believe that their work should be for the greater good, not for personal gain. Ryan also felt the same way about becoming a doctor.

> I don't want to work at really big hospitals that have a whole bunch of wealthy patients. Throw me in with people who really can't afford to see physicians when they need to see them, and that's all I need.

It is important for Catherine to "help people on a person to person level." In other words, doing work that is for the greater good of society (i.e. medical research) that doesn't involve direct care work with those in need is not something she is interested in. For 7 of the 9 women interviewed they have similar career requirements. As discussed in a previous section, these women do not see math as a "helping" profession. Their limited views of mathematics and their lack of knowledge about what mathematicians do, has erroneously caused them to rule out mathematics as a possible career.

Similarly, both Casey and Amala rejected mathematics as a career because they didn't see math as a tool for helping people. Casey explains,

> I can't be inside. I have to be with people. I want to help people. And I guess the same thing with math. I liked it, but I knew there are only so many things that I can do to help people with their lives with math, so I guess it was just something that I willingly gave up. It was a bad experience. After that I was like I really don't want to do this for fun anymore.

Amala discusses her decision to choose medicine over scientific research or mathematics as a career.

> You're not working on DNA samples, and scientific procedures. It's more of a social setting. You know, you're working with people, you're helping people, and you have to know a certain amount of knowledge, and you always have to keep up with that knowledge, but is it really *science* science? I don't know if I'm making sense, but, I think it would surprise people more if I got into research, like actual scientific experiments.

For many of these women, being in "helping" professions was very important to their personal identity. Amala implies that medicine is a more socially acceptable career because it is a helping profession, whereas if she pursued a career in scientific research, it would be less expected. She, like many other participants, have clearly identified math as a "non-social" career. Even if they can imagine ways that math might help society, they do not see it as a "helping" or "social" profession.

While the women in this study were able to recognize some of the gendered messages they received growing up, they were unable to acknowledge that gender might have played a role in their mathematical experiences. Almost all of the participants shared stories of their parents providing a counter discourse to the dominant sexuality discourse by encouraging them to challenge existing gender roles. However, the gendered message that women should be selfless and "help people" significantly influenced these participants' career decisions. Because of the way math was taught to them and their limited understanding of the work of mathematicians, the participants viewed mathematical careers as incompatible with their desire to work with people and contribute the common good.

Conclusion

In this chapter, five of the dominant discourses that influence women's mathematical experiences were discussed, including the accompanying themes that emerged from the data. In many ways, however, it is insufficient to discuss each of these discourses separately, as was done in this chapter. For, the similarities between the discourses and their overlapping influences are undeniably complex. What is clear is that the current way that math is taught and practiced in our society creates a perception of mathematics as rigid, uncreative, irrelevant, and alienating. Students are rarely exposed to the practical ways that mathematics is applied in the real world, and particularly, in mathematical careers. While the power discourse suggests that math is necessary to be successful in society, there is little evidence in this study that participants use or believe math is powerful social knowledge. In addition, the math ability discourse perpetuates the idea that few people are good at math, and that math ability is innate. Because of this, individuals who do possess mathematical ability or interest in mathematical careers are seen as deviant or "nerdy." Math ability is viewed more of a social liability than a social benefit, discouraging girls and women from expressing their interest in mathematical careers. Finally, the gendered messages that make up the sexuality discourse encourage girls and women to choose "helping professions." However, because of the way mathematics is currently taught, practiced and talked about, most of the women in this study saw mathematical careers as incompatible with their career aspirations. In the following chapter, a powerful counter discourse to these five dominant discourses will be discussed.

CHAPTER 6

SUMMERMATH AS COUNTER DISCOURSE

> Multiple, often conflicting, discourses circulate in any classroom, some dominant, others subordinate. These discourses make available to teachers and students a variety of subject positions, some of which are empowering and some not. As students in a classroom struggle to make meaning of the mathematics they are doing, they are at the same time making meaning about what it is to learn mathematics, and constructing their mathematical subjectivities (Barnes, 1996, 1).

Introduction

As will be discussed in this chapter, the SummerMath program provided powerful counter discourses to four of the five dominant discourses presented in Chapter 5. Not only was math taught in vastly different ways (D1), but the experience challenged the girls' ideas about the innateness of math ability (D2), and allowed them to meet "normal" girls and women who excelled at mathematics (D4) and (D5) (see Appendix B for summary).

Counter Discourse to the Math Discourse

As discussed in Chapter 1, the traditional way that mathematics is taught, talked about, and practiced produces and reproduces a dominant discourse about mathematics. However, counter discourses, which exist, but are often overpowered or silenced by the dominant discourse, play an important role in reinforcing or challenging the dominant discourse. For this reason, they contribute to the overall discourse about mathematics and must be given equal consideration (see CD1 in Figure 4). While participants were taught in very teacher-directed ways in classrooms where memorization and following prescribed steps was emphasized, the SummerMath program offered these participants a counter discourse to that way of learning mathematics. Here is a snapshot of a typical class period in SummerMath, in the words of my participants:

> We sat in a circle, and sometimes on the floor. It was very relaxed. We could take our shoes off, walk around, and use any manipulatives we needed to solve the problems (Catherine).
>
> We always worked with a partner (Molly).
>
> The teachers didn't really teach us, they just gave us problems to work on and then came around and asked us lots of questions (Grace).
>
> After we found a solution, the teacher would make us explain how we got that answer and how we knew it was correct. Then he would make us find another way to solve the problem. Sometimes we'd spend like an hour on one problem (Rachel).
>
> They would never give us the answers, which was frustrating at first. In fact, some of the problems they gave us had more than one correct answer (Harper).
>
> After a while, I just got into the habit of finding more than one way to solve the problems because I knew they would ask us to (Molly).
>
> All of the explaining was hard because it made us really think (Casey).
>
> We didn't cover a lot of new topics in SummerMath, but we learned how to think (Amala).

Autonomy

Autonomy usually refers to being self-governing or independent in one's actions. It implies that an individual has the freedom to make their own decisions and is not required to follow another's prescribed orders. In many ways, the SummerMath program represented a sharp contrast to the obedient nature of their traditional mathematics classrooms discussed in Chapter 5.

According to the SummerMath teacher's manual, "freedom" is one of the guiding principles of the program. It states:

> Structure can provide a sense of security for both teacher and student in the short run, but it can be alienating in the long run if structure provided is not balanced with a sense of freedom to explore. Young women need to find points of personal connection to mathematics in order to sustain continued study. At SummerMath, girls are allowed a great deal of flexibility in constructing solutions to mathematics problems. They can then structure their knowledge in a way that makes sense both personally and mathematically (Morrow and Morrow, 2000b, 8-9).

In traditional teacher-directed classrooms, students have little autonomy. At SummerMath, a student-directed program, participants described their teachers as “guides” who didn’t “feed it to you.” It is clear from their recollections of the SummerMath instructors that they appreciated the more hands-off style. They repeatedly discussed how students directed their own learning and they were responsible for their own learning. This led to feelings of ownership, a deeper understanding of the material, and increased confidence in their problem solving skills. When asked to describe what their teachers did during their math class in SummerMath, participants recalled having teachers visiting with small groups, asking clarifying questions, and providing encouragement. Teachers never gave lectures to students, but instead worked with them one on one, building on prior knowledge. Molly explains how teachers would guide students when they got stuck.

> So, if you didn’t know the answer to a problem, they would say, well, what do you know about the problem? So then you could write down things you did know. And sometimes just from looking at that, you could be like, oh get it, you need to do this. Just being able to see it in front of you would help.

And then, when students were finished with a problem, the teacher would come over to ask them to explain their thinking and ask “is there any other way you could get there?” The fact that teachers did not stand at the board and that all instruction was individualized was helpful for many of the participants. Katelyn discusses how important it was not to have to answer questions in the large group. She explains, “The teacher would come sit down at the table with you to go over things instead of you getting called up there and standing in front of her while she sat down and dictated to you. They were always on our level and very approachable.”

As discussed in Chapter 3, field observations were also conducted to substantiate the findings of this study. While it was not possible for this researcher to directly observe my participants when they attended the program ten years ago, it was possible to observe the program in operation today. Those observations not only provided context, but also supplied valuable triangulation of these research findings. For example, field observations of a recent session of SummerMath provided powerful evidence of the student-directed approach discussed by participants. When discussing the teacher’s role, the director of the program explains:

> Our job is to slow you down. When you are rushing, you’ll only see one possibility. We’re trying to help you see all of the other possibilities. In life, you might be asked to do a task. We are trying to expand your way of thinking about things (Observation 7/1/09).

Of course, some students resisted this hands-off approach to teaching at first. Ryan had difficulty with the fact that the teachers would not tell her if she was right or give her the answer to a problem. However, she realized later that that method of teaching was preparing her for the style of learning in college.

> Getting into a program like this that was like, you have to get it yourself. It’s almost like the teacher was there to just supervise, maybe guide you a little, but that wasn’t their purpose. And, so that had not been something that I had been familiar with at that time. And, I’m assuming based on this, that it probably was something that I did not like at that time either. But it was kind of like college was. The professor wasn’t there to give you the answer. So, at least I learned back then, because I probably would have been a mess in college.

In addition to teachers playing the role of facilitators instead of transmitting information, the emphasis on problem solving also allowed the participants to feel like autonomous individuals. As the participants tried to explain what made the SummerMath program different from their high school math classes, many of them referred to the emphasis the problem solving process, instead of procedural rule-following. According to Katelyn, SummerMath "was much more problem solving based" than her previous math courses. Grace, even though she excelled at mathematics explained the benefits of a focus on the problem solving process.

> I wish I had done SummerMath first because in SummerMath we did a precalculus/calculus that we could take but it was a lot different than how they taught you in class because they taught you in SummerMath how to figure out things step by step as opposed to trying to do things quickly, don't have time to spend on process, on explaining why are we doing what we're doing.

Again, at a field observation of a recent session of SummerMath, a process called "paired problem solving" is introduced to the students. The teacher begins by using an analogy:

> Robots when I was growing up would hit a wall and just keep banging up against it. Now, the new robots, when they hit a wall, they will back up and change direction. When I hit a wall, I'm going to back up and find a new strategy. You can't expect to solve the problem the first time (Observation 7/1/09).

This emphasis on the problem solving process, rather than correct answers was evident in everything they did. The teacher continues,

> We expect you to be active problem solvers in here. Active problem solvers do not just write things down…. Because if you can explain something to someone else, they you are more likely to understand it, and because that way you don't have to rely on the teacher to tell you if you are right (Observation 7/1/09).

> We are not concerned that you will finish all of the problems. We are more interested in you learning the process of paired problem solving. So we will all start on a new problem today even though you probably didn't finish the problem from yesterday (Observation 7/2/09).

According to the participants' another way SummerMath program was unique was their lack of emphasis on getting the right answer.   In fact, not only were answers de-emphasized, but they were never provided. For example, in a recent SummerMath session, the instructor explains:

> You might be tempted to ask us if you are right. I just want to warn you that we will not answer that question. We might ask you some other questions to help you think about the problem, but we will not tell you if you are right or not (Observation 7/1/09).

The teachers' refusal to tell students the correct answers to the problems they were working on clearly stood out to Amala.

> I don't remember finding out what the answers were. At first, as a group we would try to figure it out on our own. And then, ask for one of the instructors and asking their opinion on it. Honestly, I don't remember a lot about answers. I know I keep saying that, but it was never about answers, like let's go over what did everyone get or that sort of thing. I don't remember the problems but I remember it was never about going over what answers everyone got, did you get the right answer, and that sort of thing. It was like finding the right answer was not a big deal. It was not the goal of the class.

While she eventually appreciated the approach, she had difficulty acclimating at first. It had been ingrained in her that getting the right answer was important, and so when she didn't receive clear and immediate feedback that her answers were correct, it made her nervous.

> I guess at first, because I was so programmed to think about the answer and getting it right, that's what the most important thing is in school in general is getting the right answer, or getting the perfect grade, that it was sort of different. And I was like, ok, it's not even about that, and then you kind of go with the flow because it's great. It's a great feeling not having that pressure on you to get the right answer. And sometimes you'll get the right answer in a situation and have no idea how you got it. Or just not even understand it because you are memorizing a process. So, at first it was different, and then I thought, this is pretty cool, I like this, this is different.

Several participants talked about having to be "reprogrammed" to think differently about learning math. What was valued in their previous math classes was not what was valued in the SummerMath program, and therefore the expectations for students were very different. Field observations of a recent session also provide evidence of this early struggle. Feeling frustrated, a student exclaims,

> This is the most idiotic think ever! Why wouldn't I be told if a problem is right? It's a math problem. It has an answer! (Observation 7/2/09)

One of the ways problem solving is emphasized is through rigorous questioning that requires students to explain their thinking in depth. The program director talks with a pair of students about the methods they used to solve a problem:

> T-can you explain it again from the beginning?
> S- I did 1/4x + 2/5x + x = 60
> Then student writes 2/5x = 60 and (60 x 2)/5
> T-Why did you do that?
> S-Because that is how you multiply fractions
> T-Why does that work?
> S-It just does
> T-Can you explain it?
> S-No
> T-Can you find the solution in a different way, or can you draw a picture to show your answer, to represent what is happening?
> S2-I think if she finds it easier to solve it using an equation she should just write an equation
> T-But I'm not sure she knows exactly what is going on in the equation
> Student draws pie divided into 4 parts
> T-Where is 2/5 in this picture?
> Student draws two rectangles, 1 with 1/4 shaded and 1 with 2/5 shaded
> T-would you rather have 1/4 of Bill Gates' fortune or 2/5 of my paycheck?
> S-2/5 of Bills'
> T-Why?
> S-Because it's more
> T-Right, so to compare those two fractions, what needs to be true?
> S-Same size whole
> T-What does the whole 20 boxes represent?
> S-The total hours
> C-Can you use this diagram to help you solve the problem? (Observation 7/2/09)

From the participants' responses, it was clear that they had a strong desire to understand why they were doing what they were doing in math classes. They found the SummerMath program refreshing in its mission to promote conceptual rather than procedural understanding of the math they were learning, even if, at times, they were frustrated by the constant questioning by teachers.

> I just remember that everything that we did, we talked it out. It was like why, why, why. Why are you doing this? Why are you doing that? Which, at first, I'm not going to lie, I was annoyed (laughs). Because they're just like, I did it because I just know. Not this, why, why, why! But after a while you start expanding your brain a little bit more so you start, even the things with the blocks, it was just like at first, I'm just like, no, I did calculus, I'm beyond this, you know? You start to think that you're better than what they're teaching you. And then by the end, you're like, oh I thought about this completely different. This is probably what I should have been learning all along, as opposed to getting the answer right. Why are you doing it? (Grace)

Grace's story, of first being resistant to the approach and then realizing the benefits later, is a common one. Many participants, after attending SummerMath, were critical of their high school math experiences. Being exposed to this new way of learning math, they were better able to see the weaknesses of their traditional high school's approach.

Another pedagogical move that made students feel more autonomous was the emphasis on finding more than one way to solve a problem. In this setting, no one strategy or method was valued over another. Instead, students were encouraged to find as many different ways to represent their work as possible. This encouraged students to "think outside the box," be creative with their methods, and often pushed them to recognize powerful mathematical connections between strategies. For example, in a recent SummerMath session, the students were given a fairly simple problem during paired problem solving.

East Coast Problem

4/5 of the SummerMath students came from the East Coast

1/3 of East Coast students came from MA

What fraction of the SummerMath students were from other East Coast states than MA?

(Observation 7/1/09)

As an observer, it was impressive to watch the varied ways that students tackled this problem. In all, there were four wholly different strategies used to solve the problem, including manipulating algebraic equations, drawing a line, drawing a box and dividing it up into fractional parts, and finally, solving for 30 students. Students were eager to share their methods with neighboring pairs. One student said loudly, “Oh, I never would have thought to do it that way!” Her partner responded matter-of-factly, “Yes, but what she drew is actually the same thing that our equation is showing” (Observation 7/1/09).

It is true that, at first, many of the participants were resistant to this approach, feeling as if solving the problem more than one way was a waste of time. However, as they progressed through the program, they began to understand and appreciate the emphasis on the problem solving rather than on getting the right answer. Molly describes the transition from the traditional way of learning math to the SummerMath methods.

> And just doing a lot of hands on stuff and working on one problem for maybe even an hour. And there was no time limit on the work I was doing. And not being given the answers and having to explain the answers in different ways to say how I came to a certain conclusion for the answer. And, so that was kind of frustrating at first because I was like, am I right or not? And then they wouldn't tell me. And we would work in groups, so that was helpful. But still having to explain the answers and once you already have the answer, well how could you look at this problem a different way and get another answer. And I was like, well, I already have the answer, why would I have to find another answer? So, that was kind of frustrating, but then it got better and I remember we were moving through packets more quickly and being able to look at things from different perspectives and explain them in different ways better than I could in the beginning.

One of the goals of the SummerMath program is to help girls become more confident problem solvers. For Molly, that meant being better able to explain her thinking to others. For Amala, she appreciated being able to hear the alternative ways the problem was solved by her peers, as each new way deepened her understanding of the content being learned.

> I mean you can present the same problem to a whole bunch of different people, and because we worked in groups, everyone got to share how they solved the problem. So, I may look at something and look at it this way, and you look at the same thing and think of it another way. And when we converse about that, we learn from each other that way. You know, I'd never thought of it that way.

Molly continued to reflect on the problem solving experience that differed so greatly from her high school math experiences. She acknowledged that the skills that she learned in SummerMath were extremely helpful when she returned to her traditional math classes.

> At first I didn't understand that at all. I was just like, well, I got the answers, that's good enough. But I think it was because they weren't really interested in getting the answer, it was just how you got there and processes of thinking and being able to problem solve when I'm in a situation where I don't know what's going on. So, if I don't know the answer to something, just try out different things and see if I can get there a different way. And that could help in a situation in school when there are not people there telling me what to do. Or, if the teacher taught you one certain way to get to an answer, you can use your skills from that other class to look at it in different ways. So, that's how it helped me.

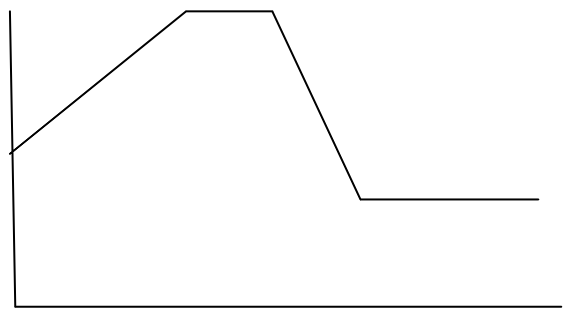
Later, Molly explained that because she knew she was going to be expected to solve the problem in multiple ways, she would "automatically" find another way to solve each problem that she encountered. This experience created a new habit of mind for Molly, as each she approached each new problem from multiple perspectives.

When I asked the participants how they adjusted when they returned to their traditional math classrooms after the program ended, many of them remarked that they missed the emphasis on multiple ways to solve a problem and on problem solving in general. They felt that the rote way of learning was artificial and superficial, and recognized that math could be taught another way. Casey especially missed not having one particular method that was most valued in the classroom.

> So it was kind of strange being back in an environment where the teacher was like no, my way is the best way. And maybe you can do it another way, but you won't get full credit for it. Whereas, in SummerMath, whatever way we got to it was fine. And everything was kind of encouraged.

Creativity also played a central role in the participants' feelings of autonomy at SummerMath. In math class, the girls were rarely given problems for which they already knew an acceptable solution method. Therefore, each problem required creativity and critical thinking. In addition, many problems were extremely open-ended, with many different solutions. For example, in the problem below, a broad array of correct responses are possible.

Think about a situation that the graph below could describe. Write a story about that situation including as many details as you can in your story that agree with the information contained in the graph.



(Morrow & Morrow, 2000a, 7-1)

Students had opportunities to be creative in not only their math class, but in their computer, robotics, origami, and architecture classes. An excerpt from a field observation of the robotics class provides a vivid example of how students are encouraged to apply what they are learning to their own personal interests and talents.

> Two girls are working on programming their robot to play Twinkle Twinkle Little Star. They spend about 10 minutes entering the program, which requires dragging icons onto a "workspace". One girl manages the mouse and keyboard while the other tells her what she should enter. After I had been watching for several minutes, one of the girls turns to me and tells me they are getting their robot to play music. I ask how she knew which codes to use for the notes of the song. She explains that she had to find the sheet music, and because she can read music, she knew what each note (symbol) stood for in letter form. Once she had the notes in letter form, she used a table of codes that was provided by their teacher to know which codes to enter (Observation 7/23/09).

Being allowed to pursue their own unique interests, these girls were deeply engaged in the learning process. Their creativity and ingenuity were valued in this setting, and as a result, the girls were far more invested in their work.

For Rachel, the creative nature of the work at SummerMath changed the way she perceived mathematics as a subject.

> I do think that SummerMath was the first time that I ever saw that attaching math to certain things could then be seen as creative, if that makes any sense. So, taking the architecture class and seeing how you had to understand math and utilize math to be able to be an architect, you know, to function within that world. But you could still be so creative. And even be creative and build this wonderful house. But if you don't have these basic math skills behind it, then your house is going to crumble. So, I that was the first time I ever saw where you had to have these principles of math, but then how they could be applied in a creative way in something that was life applicable. That was the first time that that was ever shown to me.

Grace also commented on her experience in the architecture class, explaining that she had never had the opportunity to build something like that before.

> I never had a project where you did architecture building, building, building anything. I mean, other than you drawing your poster board… The most I'd ever built was maybe model rockets for aerospace because I was in ROTC, but, it wasn't the same. Most of the model rockets you're following directions to put it together. This house, it's you, you're creating it, there's no instructions. You're building your house how you would like for it to be.

Participants also reflected on how many different opportunities there were to use math in creative ways. They discussed using computer programming in the LOGO class to make "cool t-shirt designs," attending workshops on geometry and origami, and creating and programming robots. They made it clear that they didn't really enjoy the parts of those classes where they had to follow simple procedures to do a task (i.e. learning basic computer programming commands), but instead enjoyed the time and space to apply what they learned in creative and personal ways.

Connected

Another primary way that the SummerMath differed from participants' traditional math experiences was the emphasis on connected learning. As discussed in Chapter 5, one of the primary complaints they had about math class was its lack of real world applications or connections. Morrow and Morrow (2000b) use the work of Belenky, Clinchy, Goldberger, and Tarule (1986) to explain their choice to emphasize connected learning in SummerMath program.

> As women described meaningful educational experiences (often outside of school settings), it was clear that these instances allowed the weaving together of multiple aspects of their lives. This kind of educational experience is termed connected learning, meaning that students are encouraged to build on their entire knowledge base rather than leaving all personal experiences at the classroom door (Morrow & Morrow, 2000b, 6)

One of the ways that SummerMath accomplishes this goal is through the use of context-rich problems that directly apply the math that they are learning to real-life situations. As discussed previously, these problems often take a great deal of time to complete, primarily due to their complexity. Real-life problems are complex because of the many variables that must be taken into account. The problem below is representative of the types of problems girls encounter daily at SummerMath:

Sharing Pizza

Tom, Shanta, and Jenny went to a pizza party where 5 pizzas were delivered in the beginning of the evening. (The pizzas were large and each sliced into 12 equal pieces.

1. At the party Tom ate two slices of the first pizza, one slice from the second, and three slices from the third. What fraction of a whole pizza did Tom eat that evening?
2. That evening, Shanta ate five pieces from the first pizza, six from the second, and two slices later on. What fraction of a whole pizza did Shanta eat that evening?
3. At one point in the evening, Jenny shared a pizza equally with two other people. She then shared a second pizza equally with three other people. Later, she ate another slice. What fraction of a whole pizza did she eat that evening?
4. Five pizzas were totally eaten that evening, and each person ate at least one slice. What is the maximum number of people that could have attended the party, including all of the people in the three various parts of this problem?

(Morrow, 1996, 12)

Students can solve these problems in a variety of ways (pictorially, algebraically, etc). However, it is very difficult to explain one's thinking about this problem without drawing some sort of picture. In order to be able to successfully explain their thinking, students must understand the context of the problem in depth.

Real world connections are prevalent in all aspects of the SummerMath curriculum, not just in the form of word problems. For example, students learn the basics of mathematical modeling through playing and formally analyzing the card game SET. In architecture, students learn what real-life variables and constraints they need to account for when designing their dream homes. They will need to know the approximate area a toilet takes up to determine the size of a bathroom, and the climate of the region to select an appropriate roof style. Similarly, in robotics, participants are asked to apply the computer programming skills they are learning to real-life problems. During one observation, two girls were doggedly trying to get a fan to turn on when it is hot, and off when it is cold. They quickly learn that variations in air temperature are difficult to control. They solve this problem by using hot and cold cups of water instead.

> After working for 15 minutes, the girls fill Dixie cups with water, one cup of hot, and one cup of ice water. They dip the sensor in the first hot cup and the fan starts rotating quickly. The girls squeal. “We are so awesome!” “I am so proud of us!” Then they put it into the cold cup and the fan eventually stops spinning. “It must take a while for the sensor to cool off, huh? That is why it doesn’t stop right away” (Observation 7/23/09).

Another way that SummerMath encourages connected learning is through the frequent use of journal prompts. Each day, students are asked to reflect on their experiences that day. During the second observation, students were asked to select one of the following prompts to respond to:

> How did it feel to be the problem solver?
> How did it feel to be the listener?
> How did it feel when one of the teachers came over and asked you questions?
> (Observation 7/1/09)

Not only do these prompts encourage participants to make personal connections with the learning process, but it is helping them develop metacognition skills. Students are required to think deeply about the math content they are learning, but they are asked to think deeply about the process they are using to learn math. These journal prompts not only enhance communication between teacher and student, but also helps students’ understand themselves as learners.

For many participants, this emphasis on connections and autonomous learning resulted in a change in perception of what math is and how it should be taught. Participants had many “first” experiences during their time in the SummerMath program and were exposed to new ways of thinking about mathematics, new ways that math can be applied in the real world, and new mathematical careers. During that summer, students had the opportunity to take many different courses that directly applied mathematical concepts. Students could choose from a menu of courses including cryptology, biology, computer programming, origami, robotics, and architecture. Many participants explained that they didn't have opportunities to engage in experiences like that before or after the SummerMath program.

Exposure to these different areas of mathematics influenced several participants' selection of future course work. For example, Casey explained that after taking the architecture class at SummerMath, it made her take a course at her high school.

> I liked architecture, which I didn't expect. And then I took another architecture class in high school that I enjoyed too. So just the exposure and the experience was kind of nice for me. It wasn't like a big math lesson, but it definitely opened my mind to different topics how math is used in architecture. I mean, I knew that, I didn't, but just didn't know how much fun it would be.

Later, she discussed the fact that she never would have taken an architecture class if it weren't for SummerMath. Grace said the same thing, confessing that she had perceived designing buildings as "something men do." It was common for participants to acknowledge that they took certain courses later in high school or in college because the experience in SummerMath had sparked an interest. They admitted that they probably would never have selected those courses if it hadn't been for the SummerMath program, because they had imagined those courses to be "boring" or "tedious." Similarly, Rachel took her first computer programming class at SummerMath, which propelled her to become a computer programmer. She explains how the SummerMath program changed her perception of the usefulness of math.

> I think SummerMath really opened up some different types of teaching and some different avenues of applying math and using math. I remember the computer programming class really well and I remember there was an architecture class. And kind of realizing that there were other avenues of math and different ways to implement it.

Casey explains how the SummerMath program showed her possible careers in mathematics, or ways that math is applied in real life.

> After I went to SummerMath and I saw all the applications that you could do with it, because we were able to take different classes there, dealing with architecture, and decrypting codes and stuff. Because like I said, I always thought this is just numbers and formulas and you know once you get out of school there's really no point, so, then I saw the cool things I could do.

One of the primary ways that the participants' perceptions about mathematics were changed was from being introduced to ways that math is applied in the real world. Participants acknowledged that they had a very limited view of mathematics and how it is used in real life. However, their experiences in the SummerMath program broadened their ideas of the applications of mathematics. Rachel discusses her transformation:

> Again, I think coming into SummerMath I saw math and how math was taught and how math was implemented into the real world. I never saw it implemented in the real world unless you went on to be a teacher and teach math. I never really understood what the importance of it was. I think that was the biggest transition for me, was seeing how having a background in all of these classes that I'd been taking forever in my life, how these were actually applied to other things outside of, outside of the classroom setting.

The courses that they took explicitly showed them how math was connected to those fields of study. But, in addition to that, in their math class, they were also being exposed to ways the math they were learning is applied in the real world. This emphasis on practical application was appreciated by the participants and resulted in seeing math as a "bigger umbrella" that encompasses more careers than just being a math teacher, and more skills than mere computation. Catherine explains,

> I guess we did so much with math that wasn't sitting and doing worksheets or looking at textbooks like the origami, so it did really kind of make math into something that seemed like it, it just kind of made the math umbrella seem more broad and geez, I've been doing origami since I was a kid. Of course! Why didn't I think about how math-based it was? And, so I think it did probably put math in more of a useable, and useful category.

When I asked participants if the program changed their views of mathematics in anyway, several of them mentioned perceiving math as more "inclusive" than they originally thought.

> I'll be repetitive but, just that it's not just a formula on a piece of paper. That it's basically, anything, whether or not you realize it, you look around you and everything is math. The dimensions of the room, the dimensions of your furniture, how far you have to go to get somewhere, it just made it [math] more inclusive, I think. (Katelyn)

Casey was also aware of the change in her perception of mathematics as a result of attending the program.

> And then when I went there, I definitely saw how math was applied in like different career choices and how it can be used like every day, and that was just really cool for me. I was like, oh, if you're an architect you'll be doing this type of math. And the precal class was presented in a way that was like, this is what you can do with this type of knowledge and an emphasis on what we're applying it to. So that kind of stuff was fun for me. And it kind of switched the way I looked at things… My roommate in college was a math major, and I thought that was so cool. I don't think I would have thought that was so cool like before SummerMath, like before I saw what you could do with that. I would have thought, what's the point? You know, you might as well major in basket weaving or something like that.

In other words, before attending SummerMath, Casey perceived mathematics as a useless field of study. She didn't see potential careers in the field, and might have seen it as impractical as a major in basket weaving. After SummerMath, she was more informed about careers in the field and the broad scope of applications of mathematics. Molly, too, learned that math wasn't what she thought it was.

> I learned that math isn't as boring as I thought it was before that. Or, is more extensive than I thought it was. And there are different ways to look at things and math is involved in many things that I didn't realize that it was involved in. Like, design and pretty much all the classes that they offered had some math involved, so, it opened my eyes to that.

As mentioned in the previous chapter, many participants entered the program with negative attitudes about mathematics. For many of them, however, the SummerMath program challenged those preconceptions and encouraged them to reevaluate their disposition toward math. In fact, many participants reported leaving the program liking and appreciating it much more than they had in the past. For example, Katelyn shifted from seeing math as a "requirement" to something enjoyable.

> Well, I know I'm going to have to take more math classes, but this time, I also really want to. Whereas, if we had had this conversation when I was 15 and I hadn't gone to the SummerMath program, I would have been like, oh it's my math requirement, let's get that out of the way.

Catherine, who had failed Algebra 1 her freshman year, elected to take a math class her senior year, due to her positive experience in the SummerMath program. And Amala discussed how the SummerMath program freed her from thinking about math as about grades and correct answers, and with that freedom, came greater engagement.

> After SummerMath, I didn't see it as horrible or intimidating. It was just the whole idea of not being confined to having the right answer. High school is all about the grades, getting high grades no matter what. It's all about did you get the right answer? That's all that mattered, you know? And in SummerMath it was so much more than that. How do you think about the question? So it's great to see it in that light, to look at math a little differently than just finding the right answer and equations and complete confusion.

Overall, the opportunity to learn mathematics in environment where making connections was a priority led these participants to be more intrinsically motivated and to have more positive opinions about math. They began to see how math can be relevant to their own lives, saw math as slightly more useful, and SummerMath exposed them to a broader conception of the field of mathematics. However, as was discussed in the previous section, ten years later these women still possessed very limited knowledge of mathematics careers and held beliefs that mathematics has only limited relevance to their lives. As will be discussed in a later section, this suggests that the positive outcomes discussed in this section had only a modest impact on their long-term ideas about mathematics as a field of study.

Supported

Support was another major theme that emerged from the participants' descriptions of their SummerMath experience. Unlike in their high school math classes, it was clear that the participants felt supported in the SummerMath program. Participants attributed these feelings of support to the fact that they received a great deal of individual attention each class period, could work at their own pace, and were always working in groups.

The SummerMath teacher's manual discusses the fact that as a culture, we have difficulty allowing risk-taking behavior in girls and women, wanting to rescue them at the first sign of distress. Instead, the directors of the program argue that we must provide "challenge with support" (Morrow & Morrow, 2000b, 8).

> When young women work in pairs at SummerMath, they can be asked to do very demanding work without being asked to work in isolation. They also have frequent interactions with the teacher and teaching assistant to help them focus on their work as they learn to become more self-motivated. Students become between both at persisting in problem solving and in asking themselves questions that will help them move along. In order to become confident learners, students must struggle for understanding, but they can struggle together and look to each other and the teacher for support and encouragement (Morrow & Morrow, 2000b, 8).

One of the themes that emerged as participants discussed their experiences in the SummerMath program was feeling supported. Amala was particularly attracted to the SummerMath program because it was advertised as a program for both strong and weak students. For this reason, she found the program less intimidating than some of the other more competitive math and science summer programs. In Amala's words, "they wanted everyone. They wanted different types of people, different thinkers." This made her feel like the program was a place where she could be successful.

In addition to the inclusive nature of the program, there were several other aspects that participants particularly appreciated. For example, Katelyn appreciated not having the stress of taking tests.

> I don't recall taking tests or seeing big red pen all over things, so it felt very much like an ongoing goal that you were working towards instead of just something that you had to do every day and you had to get the right answer, or else. Which made it easier to see through. It made me want to actually do well and accomplish it. Because I didn't feel like my guidance counselor was like standing over my shoulder. I don't remember there being tests, and I don't remember feeling the pressure of you have to get this right or there is something really wrong if you don't get this right away.

Instead, she felt able to focus on learning the mathematics and didn't have to worry about her performance on a test. Amala also felt the same way about the lack of formal assessments, feeling as if their absence removed a stress and helped her to focus on learning.

> It was great. There was no pressure. There were no grades to be worried about, no exams to worry about, it was just about learning, seeing things differently. And, we were learning about learning, learning about the process, and about looking at a problem from different angles, the whole process itself. Yeah, I don't remember there being any pressure or emphasis on getting the right answers at all. It was great just not to have that pressure. Because usually, you go to school, you just want to know what's going to be on the exam, and that's pretty much what you think about. It wasn't like that at all here.

Even the learning environment was described as extremely relaxed. According to Catherine, both the structure of the lessons and the physical environment made her feel more at ease in a mathematics classroom.

> It was like an open enough environment where you could talk to the person next to you and help each other figure stuff out even though we weren't necessarily working on the same thing, like bounce ideas off the people around you and that sort of thing… I remember something as simple as sitting on the floor, things that my high school just didn't do. So I just remember that it was non-traditional, relaxed but effective. You know, it wasn't like we were just sitting around kind of doing what we wanted. It was still very effective, but it was more relaxed. And I just appreciated that.

The fact that the girls could work at their own pace was another distinctive feature of the SummerMath program. Several participants referred to the long blocks of time that they had to work on a particular problem, and enjoyed having the freedom to move ahead when they were finished with a task. For example, Harper talked about how in her LOGO class she was slower than a lot of her peers but that in her geometry class, she was more advanced. In both situations she appreciated being able to go at her own pace and not feel rushed or have wasted learning time waiting for others to catch up. Katelyn especially benefited from this organization of time.

> And I liked that the blocks for your classes that you took were really nice and long because my problem with math had usually been that I would understand something when I went to school and then when I went home I would forget how to do it. So spending that much time on one thing, I would remember it from one day to the next.

Being a struggling math student, she was frequently reluctant to ask questions in class, for fear of "slowing the class down." She describes what it felt like in a traditional classroom which operates with a fast, synchronized pace and contrasts that with the SummerMath experience.

> And, you know, it would be really awkward to be like, wait a minute, wait a minute, so I was with you until you said this, what did you say five steps ago? I wasn't stopping someone constantly at a board. It was a conversation that I got to have with the teacher or the teacher's assistants or with other girls in the room.

In fact, self-paced learning is a hallmark of the SummerMath program. According to the curriculum guide, on the second day of class, "a student spends an extensive period of class time (three to seven hours)" on the assessment period where they attempt to solve problems with a partner (Morrow, Morrow & Samuelson, 2000, 6). This assessment allows SummerMath staff to effectively place students in leveled instructional groups based and to place students at similar levels in partners.

The most obvious difference between the participants' high school math classes and the ones they attended at SummerMath was class size. SummerMath classes were often taught by two instructors and several undergraduate teachers' assistants. As a result, many classes had about a 3 to 1 student-teacher ratio. According to Molly "you had that teacher available whenever you had a question" and you "definitely had time for one on one attention." Harper contrasted her SummerMath experience with her large, impersonal high school math classes.

> You get a lot more attention at the SummerMath program. At my high school, the classes were like 30 people and they'd just lecture and you'd write down lecture notes, and do the homework, and go back to class and turn it in.

Rachel also highlighted the fact that not only did she receive individual attention more frequently than she did at her high school, but she truly felt her teacher cared about her own individual progress.

> They were just much more encouraging and there to help us work through those problems. And I think it was probably one of the first times that I had a teacher that cared about how I was doing, versus how the class was doing if that makes sense.

Ultimately, because of the small class size, the instructors were better able to get to know students' strengths and weaknesses and give them specific feedback on their performance. For example, Catherine recalls the empowering and supportive evaluation she received at the end of the summer.

> I remember a letter was sent home at the end of the session from the teacher and he was just really positive and complimentary and energizing towards me and my abilities. And I remember that meant a lot to me when I got that.

Support, however, did not just come from the teachers. At SummerMath, students rarely worked alone on math problems, instead they were always encouraged or required to work with a partner. The process of "pair problem solving" is a model that SummerMath uses to help students learn how to work cooperatively in groups. In this model, one student of the pair is the "problem solver" and the other person is the "listener/questioner." The problem solver's job is to try to solve the problem, and make her thought process clear and visible to the listener. The listener's job is to ask slow the problem solver down, provide encouragement, and ask clarifying questions to keep the problem solver on task.

> The primary modes of representation in pair problem are oral and pictorial. The process makes the mental actions involved in problem solving more accessible to examination and reformation (Morrow, Morrow, & Samuelson, 2000, 4).

On the second day of class, two SummerMath faculty modeled pair problem solving by engaging in a new mathematical task. Their interactions helped students visualize the process and understand the types of questions and responses that are expected. For example, one of the requests at SummerMath is that you never erase your work, but instead, cross out your mistakes. Here, the teacher draws attention to that practice and explains its importance.

> You'll notice that Char crossed out her first attempt. If she had started to erase, I would have asked her to stop erasing. Why do think that is? …Yes, you often can learn from your mistakes and can help you track your own thinking process. I can't tell you how many times I've asked a student to explain their thinking and the student starts to erase because they assume they are wrong. Because what have been your experiences? Are you often asked to explain your thinking even when you are right? Probably not (Observation 7/1/09).

It is important to note that up until that point, most of the participants had very little experience working in groups in math class. They had experiences sitting in small groups in their math classes, but rarely worked together for anything besides checking their answers. Amala explains how SummerMath was one of her first real experiences working in groups.

> I think I started to work more and study more with people like in college than in high school. You don't really do that yet. So it was kind of my first experience working in groups. I mean you'd get group work here and there for projects, but not really everyday learning and being able to discuss concepts and things like that.

At first, some of the participants experienced some discomfort transitioning from the independent work of their high school work to the collaborative work involved in the SummerMath program. Casey, in particular, struggled with group work, but found it beneficial.

> As much as I like working with a partner, that was really hard for me. But, it did help. So, I think I would encourage some kind of partner work with, and I think it helped, the listening and explaining things. I think that would help someone like me who is so in my head with it to come out more. And it would help someone else who like, who wasn't as in their head, but maybe wasn't as strong or comfortable with math. They could hear what was being said and know the words, know the language, and be able to apply it.

Here she is emphasizing the importance of language and communication in learning mathematics. She is making an argument that more group work would require a higher level of understanding, because in order to explain something well, you need to understand it deeply.

Rachel, too, who was strong in math, remembers being hesitant to participate in group work because she couldn't hide what she didn't understand.

> I vaguely remember feeling in that class how absolutely insecure I was to show people my work. And I remember working in groups and I sometimes remember leaving just not upset about it, I think in the beginning, but, embarrassed. I think I was just really insecure about being wrong. About the possibility of being wrong or showing people what I was doing because, again, I hadn't been challenged enough up until that point. But when I got there, I was like, whoa! I hope I can do this!

For her, the act of working in groups added an additional challenge, as she was forced to explain her thinking to others. For others, working in groups represented a form of support or comfort, as students could always rely on each other for help. Molly, for example, found group work reassuring.

> Yeah, I liked working with a partner. It helped me see different approaches to a problem, or… That was the main thing that it helped me with. But also, just confirming an answer, and having someone else there to kind of reassure you, that was helpful.

As Katelyn struggled in her high school math classes, she would have benefited from being able to work with other students who could explain the math in a different way than her teachers. She especially appreciated being put in mixed ability groups.

> Unlike in school where you get placed into classes or tested into classes, everybody had a different like skill level. So that made me feel less stupid (laughs) and it made me feel good when like somebody, again, having somebody your age explain some things sometimes is better. That, sometimes I understood something better when one of the girls my age explained it to me. And I felt really good when I was able to help someone else understand something. Because I never thought I'd be giving math advice.

Within her group, she was not only able to get valuable feedback from her peers, but she was able to gain confidence in her own math ability. She began to see herself as a knower of mathematics and someone who had something to contribute to the group. Grace, on the other hand, struggled working with her partner in SummerMath. She explains,

> SummerMath actually forced me to always work with partners, whereas no other place made me do that. I would always just choose, oh, I can do it by myself. I don't need anybody, I just need myself. I never realized what a benefit it is to bounce ideas off with other people. It makes it so much better and makes things go by so much faster than just being in a world by yourself.

Ryan appreciated being able to work in groups at SummerMath because "you are allowed to kind of bounce your ideas off the other person." Interestingly, Molly uses the same language to describe why she likes working in groups.

> I like working in groups because that way I can bounce ideas off of other people and see what their thinking was to solve a problem and compare it to my own or even just look at it a different way of solving the problem that might be interesting as opposed to the way I solved it. And, yeah, sometimes just the reassurance of other people. That, oh, we got the same answers but we got it different ways. I feel better about it.

According to the participants, one of the benefits of the experience was their increased ability to explain their thinking about solving mathematical problems. The program also changed their perception of "showing their work." Casey, for example, was extremely resistant to showing her work, because she felt it took unnecessary time and was merely to prove that she had not copied her answers from others. She admitted that after attending SummerMath, she was much more "open to showing her work." Ryan was also initially resistant to explaining her thinking in SummerMath. But, ten years later, she finds herself asking the student she tutors to explain his thinking. She says,

> I'm wondering, because I tutor a kid in math and I do this with him. I have it so that he's the teacher and I don't know what's going on. And I let him do the problem and then once he finishes it, he explains why he did everything. And I must have got that from SummerMath.

This is an excellent example of how the counter discourse of the SummerMath program left an imprint on Ryan's ways of thinking about and teaching mathematics. She was not necessarily aware of the connection until this interview, but clearly the SummerMath program left its mark.

Outcomes

The SummerMath program offered students a counter discourse to the dominant mathematics discourse. Math was talked about, practiced, and taught in very different ways than the participants had previously been exposed to. The unique style and mission of the SummerMath program resulted in several positive outcomes for participants. Three types of outcomes were identified from the data and will be discussed below.

Problem Solving Skills

As participants reflected on what they gained from their SummerMath experiences, they discussed the flexible problem solving skills that they learned. For example, participants learned new strategies to solve problems and new ways to think about solving problems. Molly discussed learning how to "lay out a problem" and think about it "systematically in different ways." Rachel learned more about herself:

> It made me want to be challenged more academically, intellectually, I mean, you could say spiritually and culturally, it just made me want to experience more, it made me want to be challenged more. I think was the biggest thing that I took away there.

Molly also suggested that her improvement in grades after SummerMath had to do with the problem solving strategies that she learned while she was there.

> Well, when I got back to school I was able to use these techniques that I learned at SummerMath to get through the problems, and if I wasn't able to, to try a different way to get through them. Or, to lay out the problem in front of me using a kind of blocks or something like that to figure it out. And although it may have taken more time, it helped me understand the concept, so when it got time to come into the test, I would know what I was doing.

This emphasis on the problem solving process instead of correct answers also encouraged participants to want to understand the "why" behind the procedures they were learning. As a result of this desire, it not only led to a deeper understanding of the material, but also a different attitude about mathematics in general. Grace, the accountant, discussed how the SummerMath program taught her to really understand the concepts being learned, rather than just memorizing them.

> My patience was improved to sit and try to figure out, not just do it this way, but why am I doing it. Which I apply in everyday work life. I think that's what the people at [Accounting Firm 2] always say that what they can say about me as opposed to anyone else, is that I just don't do things, I try to understand what it is I'm doing and understand the concepts as opposed to just doing because 50 people before you did it just like that so that's how you're supposed to do it.

For Molly, her interest in math increased because of the focus on understanding why. She began to see the relevance of the math she was learning, and made the effort to understand the steps she had been obediently following in high school.

> I guess it just made me see the different components of what is involved in math, like how all those classes tied into math and that some people actually took the time to make sure everyone understood things and so that made me more interested in being a part of it, if I was really going to understand what I was doing, and not just go through the motions.

While Molly never learned to love mathematics, her approach to learning math had changed. She placed more emphasis on "understanding what she was doing" and as a result, she was more successful in her future math courses.

Persistence

The SummerMath program is intentionally designed in such a way that it requires participants to have a great deal of persistence in problem solving (see Appendix A). Assigned problems would often take the entire 2.5 hour block to solve, and projects in the workshops might take all five weeks to complete. As students were working, teachers were readily available and would talk through the problem with students, but they would never tell a student how to do a problem or tell them the correct answer. This process is a very different way of doing and learning mathematics that what participants were used to. In their high schools, they might complete 10-30 problems per class period, and usually the answers were "checked" at the end of the lesson. Emphasis was on executing prescribed steps to obtain a correct answer, rather than on real problem solving to find a solution. In that type of classroom, students are rarely asked to persist very long on a problem without being told what to do, and usually answers can be found in 2 minutes or less. If a problem takes a student longer than that, it is a signal to them that they "don't know what to do" so they should ask for help.

Needless to say, when the participants entered the SummerMath program, they struggled to adjust to this style of learning. However, as they reflected on the experience, they acknowledged that they learned to be more patient and persistent. For example, Ryan was someone who wanted to complete her work quickly when she entered the program.

> I think with that one aspect of it, it calmed me down a lot. I'm not saying I was some hot-head if I didn't get the answer, but I was almost borderline a hot-head if I wasn't given the answer. If I tried a couple times, and still you were like, well, try again, no, I don't want to try again. No way. (laughs).

For Katelyn, she learned that if she put enough time and effort into her math work, she was a capable math student.

> I instantly saw the difference, that it was just a matter of spending enough time on it. And, being in that environment where I had the resources to ask multiple people. So just spending more time on it, and not saying I tried it seven times and I still don't get it and it's still not working, so I give up. After SummerMath I was much more patient with myself.

Rachel too, had a history of giving up easily in math class.

> I had never really been challenged. So I think when I was challenged, I would give up easily. And so I think that it just kind of encouraged me to push a little bit more, and I learned how to work through problems. Probably a lot better in that course than I did in any other class, any other math class that I took before or after that.

Finally, Grace recollects how the SummerMath program helped her learn to be more tolerant of others difficulties in math, and enabled her to be more patient with herself and others. She asserts,

> The only way I was ever able to help people study, especially with math, is after doing SummerMath. Because before, I never had the patience. And this, they really did test my patience.

She continues,

> I must say, me as a tutor pre-SummerMath and post-SummerMath are like two different people. My patience level is, because I'm telling you, those first couple of classes when it was like, why, why, why, my patience was definitely tried. But after a while when you can say, oh, I should take the time to actually think about why things are being done, as opposed to just doing it. You start looking at things in totally different ways.

Confidence

In addition to increased problem solving skills and persistence, one of the most frequently mentioned changes that the participants described was an increase in confidence and feelings of empowerment (see Appendix A). One reason they might have felt more confident was because they had been doing math over the summer, so the material was fresh in their minds. For Katelyn, Casey & Ryan doing math over the summer actually increased their interest and performance in math class.

> Maybe because I had, because mainly because I wouldn't have used that part of my brain over the summer and I had, so I felt more awake walking into the beginning of the school year, having it more freshly in my memory. And being proud of myself. I was still like feeling that and ready to do that in the classroom (Katelyn).
>
> I've been doing math like every day. So it just felt like I hadn't really paused and I didn't have, you know, I used to feel like, oh the summer, and then you go back and you have to like relearn some things. And since I had been doing it, I felt ready and I just felt like, oh I can do this (Casey).
>
> It probably made me a lot confident because here I was doing, you know, I kept my brain active during the summer which is not something, I guess a lot of students do. You know, summer is like your chill time, so you pretty much forget everything. Um, and then I got into that precalc class and I was just whoopin' everybody (Ryan).

Catherine also felt that doing math over the summer improved her confidence level.

> I'll try to describe this correctly, kind of like I felt sort of special, you know that I had done this thing that summer that nobody else in my class had done and I spent a month at this university doing math, and I think that I felt special about that and a little bit of maybe like a pride and maybe like a want to not show off, but kind of use my new confidence and skills and that sort of thing.

She felt "special" because she had an opportunity to do math over the summer, an experience that gave her a small advantage over her peers. That feeling of "specialness" was enough to make her feel like math was a subject she could excel at, which was very different from her original attitude. She also attributed some of her increased confidence in the single-sex environment.

> I guess it was just a really empowering environment, and I keep using that word a lot, but I think that I benefited from not just the specific math curriculum but from the atmosphere, and the single-gendered atmosphere of it all. I felt it just maybe re-sparked some of my interests, and ok, I can do this. And I'm sure that learning different strategies for approaching things, and being around all these really intelligent women who were the RAs and instructors that who I really looked up to, and other girls around me…

Being around a group of women whom she respected and looked up to, who enjoyed doing mathematics, buoyed her confidence in her own math ability. Her experience illuminates the importance of having same sex mentors in mathematics education. Other participants also told stories of increased self-confidence in math class and beyond. For Ryan, SummerMath gave her the confidence to continue taking math courses, even though they were elective and she would have to attend class in a different school because they weren't offered in her school. She suggests that the program "is what probably gave me the nerve to even say, I'd like to take calculus. And have to venture outside of the school." Rachel, too, felt that the program not only improved her confidence in math class, but also in other parts of her life.

> I'm sure that it improved my math skills and on an overall basis. And I think I have mentioned this before, I think that it was just, more than anything else, I think I learned to be a little bit more confident in myself, which is something that I didn't have before coming into SummerMath.

When I asked participants what it was about the program that they felt led to their increased confidence, many of them suggested that the progression of topics, and the emphasis on understanding the material allowed them to feel successful in doing mathematics, perhaps for the first time in their lives.

> I felt really confident in that class just because the material was presented in a way that I thought everything in there was really easy. Not like I was smarter than anyone, I think everyone handled the material really well in that class. So I guess it just made me more confident. I don't know if they were trying to make it that way so that you'd become confident in math. And the classes were small. That was good too. I do remember feeling really confident like oh, I'll participate, which is something I don't do a lot. Just because before that I had done so bad so I felt like I didn't know anything about math.
> And then after going there, I was like, well I do know something about math. (Casey)

Others discussed the specific feedback they received from their instructors. They contrasted the personalized and supportive messages that they received from their SummerMath instructors with the impersonal and corrective or evaluative feedback they got from their high school math teachers.

> After a few years of middle school and high school I just felt like math was just something that I couldn't do. I just remember the teachers really making students feel really good about their specific abilities and helping to develop other abilities. I just remember that specifically.

As a result, Catherine left the program aware of her own mathematical strengths and believing that she could be successful in a math classroom. Casey attributed her post-program math success to the fact that she felt more confident and "knew the formulas and everything." Several participants explained that it was beneficial to attend the SummerMath program because it gave them a preview of the upcoming content, and gave them a space to feel confident in their math abilities. For Katelyn, after attending the program was the first time she earned an A in math class. Amala had a similar experience:

> I went from struggling to getting some of the highest grades on my tests in the class. And I think my positive experience with SummerMath definitely had something to do with it.

When I asked the participants how the SummerMath program influenced their math experiences after they left the program, many of them argued that the program helped them to improve their high school math grades. For example, Catherine, who had failed her Algebra 1 class, reflects on how the program impacted her:

> I think the fact that I kind of had forgotten exactly how hard of a time I had my freshman year with math probably speaks leagues of my experience with SummerMath. Because I just remember, now that I think of it, I remember taking Algebra 2 and Geometry at the same time, and I just remember, it just wasn't that bad. And, just reading how I felt about math before I went into SummerMath and kind of remembering how much I did struggle, I don't know, it was just really crazy to read. And I just think that SummerMath maybe really impacted me more than I realized. And thinking about it so intensely in these last interviews, even more than I remembered then.

Conclusion

In addition to becoming better problem solvers, more persistent, and more confident in their math ability, several participants reported learning more about the field of mathematics. Many of them expressed resentment and feelings of being "cheated" because the methods employed in the SummerMath program were not used in their high schools. They firmly believed that if those teaching practices had been utilized, they would have been more successful in their math classes, would have felt more confident in their own math ability, and would have liked mathematics more. For some participants, these incidents of consciousness raising led to resistance or forms of opposition. For example, Casey passionately retells the story of standing up to her math teacher, who was insisting there was only one best way to solve a math problem.

> So he taught his way and that was the only way. And I didn't do it that way, because I had so many ways to do all sorts of stuff. And so I wasn't afraid to write that up on the board, because he would call on you and then he would say, no that's wrong. And I said, "but I got the right answer." And he said, "well I like it this way." And I responded by saying, "but it's not the only way." I would have never done that if I hadn't gone to SummerMath. I never would have gotten up and I never would have told the teacher, no, I'm still right and I'm still going to do this on a test, and I'll tell my mother and the board, the board person if you like mark me wrong for having the right answer.

Her experience in the SummerMath program exposed her to other ways of learning mathematics, ways that she perceived to be more effective and beneficial to her style of learning, and fought to have those methods valued in her high school classroom.

Participants admitted that they didn't remember learning much new mathematical content during their stay. However, they learned strategies for solving mathematical problems, they learned about themselves as learners, and they learned about the field mathematics. While it is impossible to tell if the program had a direct impact on these participants' high school math grades after attending the program, there is a clear pattern of improvement among these participants. This trend seems to suggest that the program at least has some modest positive effect on the students' academic performance in math.

Counter Discourse to the Ability Discourse

Related to these feelings of increased confidence are changes in the participants' perceptions of their own math ability. It is difficult for a person to feel confident if they don't believe they have the skills necessary to be successful in that arena. Many of the participants started the SummerMath program believing that they had very low math ability and believing that their math ability could not be changed. However, it became clear that several participants dramatically changed their ideas of their own math ability by the end of the program. Katelyn, who had rarely passed a math class, left SummerMath with a renewed belief in her own abilities.

> I think I learned I just needed time and someone to talk to me about it. That I was very capable of doing it. So I came to learn, if I took the time to do it and someone took the time to explain it to me and I got to go over it again and not just skip it and move on and forget it, that it would stay with me and it was something that I could be good at it if I got to spend that much time on it. It was a really nice feeling of accomplishment because I had always been so bad at math, to be getting these things right made me feel really good because it was something I had basically given up on.

Casey also came to believe that she was good at math. Her comments are typical of other participants who had discussed similar changes in their perceptions of their math ability.

> And once I went to SummerMath, I felt like oh I really am good at math. I can understand it if I try. And yes, I didn't like geometry, but that's ok. I can still do other types of math. It doesn't mean I'm not good at the math. It just means I will never look at a proof again (laughs).

Rachel had a different revelation as she was challenged in the SummerMath program.

> It probably dawned me like oh, I'm not as great at this as I probably thought I was, but I can be, I just have to push myself to be, more so than I ever have before. In high school I was never challenged, I was never pushed. So, I think that it was, it was very eye opening in that sense that I probably, I had never had to ask for help really. I just understood things and I did them with ease. And at SummerMath I was being challenged and I was being pushed, so that was whole new experience for me in a classroom setting.

Clearly, her perception of her own math ability changed as she was challenged and exposed to a new way of learning and thinking about mathematics. She was not discouraged by this new experience, but instead obtained a more realistic understanding of her own math ability.

Counter Discourse to the Deviance Discourse

One of the most obvious counter discourses to the deviance discourse (CD4 in Figure 4) that emerged from the data was the SummerMath program. As discussed previously, the presence of so many women who excelled at mathematics as instructors, counselors and students normalized the behavior for the participants. They began to see that "people just like me" can be good at math and still have a social life. They realized that there were people who they truly liked and respected who were passionate about mathematics. As a result, they were better able to see themselves in the same role and began to see math careers as a reachable goal for themselves.

In addition, the pedagogy used in the SummerMath program played a role in normalizing math ability. All of the girls were successful in their math classes, and it was expected that they would all participate and succeed. It was a rare situation where math ability was the expectation, not the exception to the rule. Girls who had previously identified themselves as mathematically able and interested in mathematical careers were able to meet other girls with similar interests and abilities. This, again, helped them to see themselves as "normal." Finally, they gained exposure to inside world of mathematician's work, thereby demystifying it and challenging any preconceived notions about the field.

Lastly, with this new perception of mathematics came new ideas about who should do math, and the stereotypes about people who excel in math. In many ways, after attending the program, participants perceived math ability as much more "normal," and therefore, less deviant. Molly reveals her preconceptions about people who "do math," explaining that her image of mathematicians changed dramatically after SummerMath.

> Yes, it made me have more of a respect for, you know, people get bad reputations. It's not just numbers, it's not just dorks who do math. It's involved, you know, from learning that it's involved in a lot of things, design and other things like that, it made me see that.

The way the math was presented to her resulted in a shift in the way she perceived the field, but also a shift in her perception of individuals who do mathematics. Learning that math is applied in lots of different fields created a whole new image of mathematicians for Molly.

Katelyn also left SummerMath viewing mathematicians as more "regular" but for different reasons. In her case, it was being able to identify with women who excelled at mathematics that helped her to see herself in that role. She recalls one of the teaching assistants, whom she viewed as being very influential to her.

> I liked that she was really funny and really approachable, and I guess I was expecting a bunch of nerds in Birkenstocks that were really nerdy and boring. And she was just like, a lot of fun. So, to see someone that I liked and that I could identify with be really good at math and be able to explain things about math to me in a way that I understood, so then she wasn't just some nerd I couldn't relate to that was just like hyper intelligent. She made me feel more like so long as more regular people are interested in it and try, that you are capable of doing it.

This person was someone that she liked and respected, and with whom she identified with because she had also come from a similar socioeconomic background. Being around women who were passionate about mathematics, but who also considered "normal" challenged their previously held beliefs and stereotypes about mathematicians. Rachel later explains why she chose a career in graphic design when she says, "I loved being able to be creative and use all of these skills that I had developed." In fact, she claims that the first time she ever realized that computers could be used in creative ways was during the LOGO class at SummerMath.

> And we got to kind of design things on the screen and that was the first time I was like this is kind of cool, this is neat, this is fun, I could do this all day. I looked forward to going there every day. And so when I got back I kind of tried to find somewhere for that niche. I was very interested in that creative thought. I really enjoyed art. I really enjoyed pushing myself, but also the technology side that could be in computers, so I think that's why I started leaning towards mass communication and more towards graphic design.

Counter Discourse to the Sexuality Discourse

Despite the existence of the dominant discourse about gender in general, and women and mathematics in particular discussed in Chapter 5, there are counter discourses being created and maintained each day to challenge those dominant ideas (CD5 in Figure 4). The single-sex environment of the SummerMath program, which encourages and supports women's participation in male-dominated mathematics is just one example.

At first, when participants reflected on the single-sex nature of the SummerMath experience, they had little to say. In fact, many of them suggested that the fact that the program was single-sex "didn't make a difference." That being said, the women did eventually acknowledge some benefits to the single-sex environment. First, many of them expressed appreciation for the reduction in social distractions. For example, Grace explains why she preferred the single-sex environment:

> I thought it was good. I know when I was growing up I was never particularly boy crazy, so, but sometimes the girls were just a little bit too boy crazy for me. So, when there are no boys around, it's easier to get things done. You not trying to be distracted to flirt with this person, especially by the time we got to high school. It was good to not have to just deal with the flirting, everyday, the drama of this person's boyfriend, that person's. I almost think that it would probably better for girls if they were in environments where it was all girls as opposed to mixed. I know that sounds horrible, I think it would probably be best for their learning so they could concentrate (laughs).

Other participants discussed the fact that they were better able to concentrate on their school work and to make deep lasting friendships because they were not competing for boys' attention.

Beyond freedom from distraction, many participants explained that the single-sex environment was more "relaxing" and made them feel more "comfortable." Ryan felt a palpable difference in the atmosphere, saying it was "calm" and "safe." She says,

> I think after SummerMath I realized that being in the all girl environment was relaxing. All I had to worry about really was trying to learn the math. And trying to learn all the stuff they were making us do on the computers, and everything else we were trying to figure out.

For Casey, an all-girls environment made her more willing to participate in class.

> But, boys definitely call out more in class, and I guess being in a single-sex environment that gave me a chance to participate more because I'm not the calling out person at all.

Harper, who argued that being in class with boys was "not an issue" admitted that "It was weird, I guess, not to have guys around, but, no I think I was probably more comfortable for some reason." While she couldn't articulate what it was about the single-sex environment that made her feel such comfort, by acknowledging this greater sense of comfort, she is revealing at least a small amount of discomfort in her coeducational math classes.

In addition to these feelings of focus and comfort, the participants discussed feelings of greater self-confidence and empowerment as a result of the single-sex environment. Harper described the opening speech at the beginning of the program:

> I think they always brought it up in the introduction, with like talking about, just kind of affirming girl power sort of thing. I think they just like ask lots of questions to try to get girls to raise their hands and be like, yeah, I'm part of this. So I think they probably ask questions about your math classes. I don't remember the specific things, I just remember lots of people getting really excited.

What is surprising about Harper's response is that when asked how the program affected her, she replied with a description of how it affected "lots of people." She mentions "affirming girl power" in an off-handed way, as if trying to distance herself from this empowerment, and sending the message that she didn't need this type of empowerment. The program was clearly trying to help girls claim math as an identity and create a sense of belonging by having girls say "I'm a part of this." This sense of belonging or claiming math as an identity had been identified as a critical part of creating equitable k-12 education (Herzig, 2010).

Harper recognizes that community building was happening at this program, but she doesn't want to acknowledge that she benefitted from it. She remembers "others" being excited, but not her. One would assume that a young girl with a passionate interest in science would love to be surrounded by other girls with similar interests. Her resistance to admit that the program helped her is very revealing of the dominant sexuality discourse at work. For, if she admits the program helped her, she is admitting she needed help. And by admitting she needed that sense of community would expose the fact that a sense of community does not already exist for women in math and science.

It appears that the dominant sexuality discourse is so powerful that even girls like Katelyn, who admitted that she benefitted greatly from the single-sex environment, argue that "single-sex schools are crap." Ironically though, she is the same participant who became passionately angry when a boys basketball team was allowed to use the facilities during their stay.

> I got very territorial when they let that basketball team come over to use the pool. Being really pissy that like, I was really excited that I usually wear shorts or something to go to the beach. I don't like being looked at. And, just in general, in public it really bothers me. I hate people whistling at me and stuff. And I remember being really mad that they were allowed to use the pool and I couldn't just go in my bikini like I had done with all the other girls. That it made me uncomfortable when they were around.

Katelyn was not the only one to mention this boys' basketball team during their interviews. In fact, almost all interviewees discussed feeling "invaded" or encroached upon and wishing that the boys hadn't been there. They discussed how instead of the girls hanging out together in their free time as they had done the first two weeks, once the boys arrived, many of the girls would go sit and watch the boys play basketball. Many participants expressed frustration with this distraction, and greatly valued the all-girl environment that had been created.

Overall, the single-sex nature of the SummerMath program provided an alternative discourse to the dominant sexuality discourse. The program made the girls feel comfortable, freed them from the surveillance of boys and men, and suggested to the girls that women belong in the mathematics field.

Summary

One of the many strengths of the SummerMath program was that it provided counter discourses for four of the five dominant discourses examined in this study. SummerMath offered a powerful example of how mathematics can be taught in different ways, emphasizing autonomy instead of obedience, connections instead of coverage, and support instead of competition and individualized work. The math ability discourse was also effectively challenged as many participants began to believe that math ability was something that was changeable and not innate. Introducing girls to women and other girls who both enjoy and excel at mathematics also played an important role in countering the deviance discourse. Finally, the single-sex environment provided the girls a safe place to take risks, and indirectly countered the sexuality discourse. However, as will be discussed in the following chapter, many of the positive short-term outcomes of the SummerMath program did not necessarily carry over into their adult lives. The reasons for this limited impact will be explored in Chapter 7, along with areas for improvement that might result in more long-term changes in girls' and women's interest in mathematics careers.

CHAPTER 7

DISCUSSION

Introduction

Chapter 6 illustrated how the five discourses in the original theoretical framework of this study manifested themselves in the participants' stories. This chapter will focus on the themes that emerged from that data and how they fit within the context of the research literature on this topic. In particular, the mathematics and sexuality discourses will be highlighted as the primary influences on women's career decisions. This chapter will also introduce a revised theoretical framework to further explain how various discourses influence women's mathematical experiences over time. A partial explanation of both the short-term success of the SummerMath program and its inability to make long-term differences will also be addressed. Finally, the feminist standpoint theory, which was one of the guiding theories of this study, will be reexamined.

Revised Theoretical Framework

The findings from this study revealed various weaknesses in the original theoretical framework presented in Chapter 1 and revisited again in this Chapter 6 (Figure 4). That theoretical framework was a strong starting point for identifying key discourses that play a role in women's choice to enter mathematical careers. However, the original model did little to recognize the relative weight of each discourse, when those discourses were most influential in a girl or woman's development, and significant ways that those discourses intersect at various points in a woman's life.

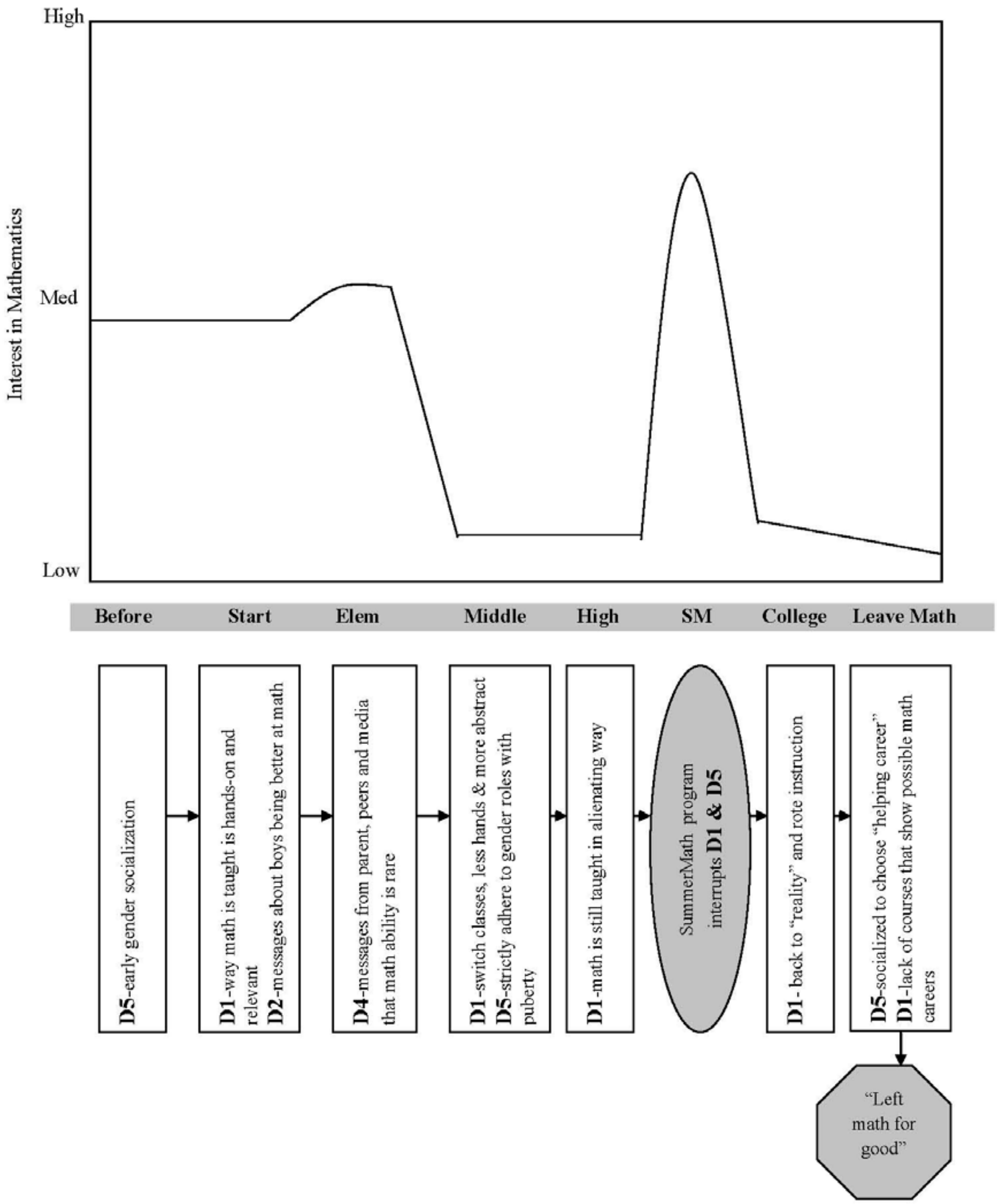


Figure 5. Interest in Mathematics over Time

The revised theoretical model (Figure 5) offers a visual representation of the relative influence of each discourse over time. For example, the stories that women told and the discourses they used to tell those stories highlight the predominant role that the mathematics discourse (D1) and the sexuality discourse (D5) play in girls' and women's decision to enter mathematical careers. In Figure 5, it is apparent that the mathematics (D1) discourse plays the largest role in girls' interest in mathematics over time. It is also clear that the sexuality discourse (D5) is central to girls' mathematical experiences, and that the influence of that discourse increases over time. The math ability discourse (D2) and the math deviance discourse (D4) are more influential in girls' early mathematical experiences and its significance decreases over time. The math power discourse (D3) was rarely referenced and seemed to have very little impact on these women's mathematical experiences.

The Road to Nowhere

The stories that these women tell about their mathematical experiences are surprisingly similar in both their content and their form, despite their differing geographic and educational histories. Virtually all of the participants, even Harper and Grace, who went on to pursue math and science careers, characterize their mathematical learning as a "bumpy ride" (Casey) in a car of which they did not control, down a boring road that seemingly "lead to nowhere" (Catherine). Most of them got out of the car as soon as they could, with no clear idea of where they ended up, or why they made the journey at all.

Early on, participants described feeling a moderate level of enjoyment in mathematics. During that time, participants described being influenced by early gender socialization (D5) and received messages about boys being better at math (D2). However, it was the way math was being taught to them (D1) that was the primary influence on their interest in mathematics during that early period in their lives. As they progressed through late elementary school into early middle school, they began hearing messages from parents, peers, and the media about the rareness of math ability (D4). Upon entering middle school, math class became even more abstract and less personalized as participants graduated from self-contained classrooms (D1), leading to a dramatic decline in enthusiasm for mathematics. Also during this period of early adolescence, participants were particularly sensitive to gender stereotyping (D5). They were much more likely to feel the pressure to conform to expected gender roles with the onset of puberty and dating during the middle school years. As participants entered high school, math continued to be taught in a formulaic and disconnected way (D1), resulting in even less interest in mathematics as a field of study.

At some point in their high school careers, the participants entered the SummerMath program. While there, they experienced new ways of learning and thinking about mathematics (CD1). In addition, they had opportunities to meet and form relationships with many other girls and women who liked and excelled at mathematics (CD5). The single-sex environment temporarily interrupted the dominant sexuality discourse (D5), and challenged gender stereotypes (CD5).

However, it appears that the temporary interruption of the dominant mathematics (D1) and sexuality (D5) discourses was not enough to increase the participants' long-term interest in mathematics as a potential career. After leaving the SummerMath program, the girls went back to "reality" and math instruction that emphasized rote memorization and procedural learning (D1). The participants, for the most part, excelled in these high school mathematics classes, but saw them only as requirements for college admission.

Upon entering college, the participants reported seeing the math they were learning as disconnected, and experienced tremendous frustration with their lack of conceptual understanding of the mathematics being taught (D1). Similarly, the women described feeling social pressure to select a “helping career” (D5) early in their college careers. They viewed the math that they were learning as irrelevant and lacking in real world application. They desired careers that would contribute to society, and did not see ways in which careers in mathematics could accomplish that (D1).

The way these participants chose to phrase the end of their math coursework is also significant. For, when someone stops taking English classes in college because they are in another major, they might say, “and that was the last English class I took.” Ryan, instead, uses the word “left” like leaving an abusive lover, or a bad job, or a boring movie. It implies a conscious choice or action and is usually to avoid something negative or to move to something more enjoyable. It is about “leaving behind.” It also means, if she left it, that she didn’t take any of it with her.

In particular, this revised theoretical model helps to illuminate why the SummerMath program had such positive short-term outcomes but will continue to be limited in its ability to achieve long-term changes in girls’ interest in mathematics. When considering the age at which the participants entered the SummerMath program, the two discourses that had the greatest relative importance were the mathematics (D1) and sexuality (D5) discourse. As discussed previously, the reform-based pedagogy (CD1) and single-sex environment (CD5) of the SummerMath program served to interrupt those dominant discourses at a critical time in the participants’ social and emotional development. The program was also successful in challenging the math ability discourse

(D2) by perpetuating a growth mindset for math ability (CD2). SummerMath also provided the girls with many examples of real life mathematicians, which made mathematical ability more normal and less deviant (CD4). In fact, one of the strengths of the program was its ability to effectively counter four of the five dominant discourses that influence girls' interest in mathematics. However, the transformational experience that many participants described was still not enough to encourage them to enter mathematical careers. While the girls enjoyed their experience in the SummerMath program and briefly increased their interest in mathematics as a field of study, upon returning to the "real world" of school mathematics, the effects were not lasting. The SummerMath program could do little to influence the way mathematics is taught, talked about, or practiced at the college level. Nor could it change the dominant sexuality discourse that dictates expected behaviors for girls and women. Thus, the dominant mathematics (D1) and sexuality (D5) discourses continued to operate on the participants after they left the program, thereby limiting the long-term results.

Unfortunately, this theoretical model is limited in its ability to represent interactions between and among discourses or the influence of counter discourses. Nonetheless, it provides the reader with a clear depiction of which discourses are most influential at any given point in the girls' development, and which discourses are most influential overall. Armed with this information, practitioners and policy makers can begin to make more informed decisions about the types of interventions that might be most effective for a specific age group. And most importantly, this model portrays the complexity involved in girls' career decisions. Using this theoretical model, it is clear that providing one intervention to address one discourse at a specific age is not going to make girls more interested in mathematical careers. Instead, this problem will require far more large-scale interventions that are capable of addressing each of the discourses at varying points across school types.

Math Discourse: Boxed Brownies

The stories that these participants share may resonate with many readers. For, unfortunately the practices in school mathematics have changed very little over time, despite calls from the NCTM (2011) and evidence from math education research that suggests these practices do not lead to long term conceptual understanding of mathematics.

Overall, these findings are consistent with other research literature on this topic. First and foremost, it was unsurprising that girls report feeling alienated, bored, or dissatisfied with K-16 math education. Boaler & Greeno (2000), among others, have reported girls portraying their high school math experiences as highly ritualized in that teachers demonstrate procedures and students practice them. This discourse of *obedience* continues to operate in sharp contrast to recommendations made by the National Council of Teachers of Mathematics (NCTM):

> Learning the "basics" is important; however, students who memorize facts or procedures without understanding often are not sure when or how to use what they know. In contrast, conceptual understanding enables students to deal with novel problems and settings. They can solve problems that they have not encountered before. Learning with understanding also helps students become autonomous learners. Students learn more and better when they take control of their own learning. When challenged with appropriately chosen tasks, students can become confident in their ability to tackle difficult problems, eager to figure things out on their own, flexible in exploring mathematical ideas, and willing to persevere when tasks are challenging (NCTM, 2011).

In many ways, learning mathematics is analogous to learning how to cook. Consider the scenario of making brownies from a box. One of the benefits of using boxed foods is the reliability of it. It is fairly easy to follow the directions, complete with pictures of the necessary ingredients. In some ways, making boxed brownies can be an effective way to learn to cook, for early success is fairly certain, and basic skills such as cracking eggs, measuring, and mixing can be practiced. However, very few people would actually feel confident in their cooking skills if boxed brownies, macaroni and cheese, and frozen dinners were all they knew how to prepare. After all, those items require only the ability to follow directions, and a few basic skills. Few people would boast about their ability to make "really good" brownies from a box. For, while the ability to make boxed brownies without burning them distinguishes someone from a few poor souls that don't know how to turn on a stove, it doesn't say much about a person's actual cooking prowess. I will make the argument in this section that participant's mathematics experiences were similar to learning to cook by making brownies from a box. While the procedural nature of the tasks made it fairly easy for participants to be successful, they possessed limited confidence in their own mathematical abilities.

The question of why individuals obey in mathematics classrooms is a more difficult one. In the case of Milgram (1974) and his famous shock experiments, individuals claimed that they assumed the person in authority knew best. They saw the experimenter as a scientific authority and trusted that they would not be asked to do anything dangerous, unethical, or incorrect. It is possible that those participants might also have feared the negative consequences of refusing to continue delivering the shocks, such as embarrassment, disapproval by the researcher, etc. Finally, perhaps it was simply easier to continue obeying authority than to think for oneself and resist the orders being given.

According to Milgram (1974), it isn't that people who obey have given up their morality or reason when they obey. Rather, they have reconstituted how they judge their own behavior in that particular situation.

> Although a person acting under authority performs actions that seem to violate standards of conscience, it would not be true to say that he loses his moral sense. Instead, it acquires a radically different focus. He does not respond with a moral sentiment to the actions he performs. Rather, his moral concern now shifts to a consideration of how well he is living up to the expectations that the authority has of him. In wartime, a soldier does not ask whether it is good or bad to bomb a hamlet; he does not experience shame or guilt in the destruction of a village: rather he feels pride or shame depending on how well he has performed the mission assigned to him (Milgram, 1974, 7).

The participants in this study responded in similar ways in their mathematics classrooms. Not only did they see their teachers as mathematical authorities, assuming that they knew best and distrusting their own intuition, but they evaluated their own performance based on how well they were meeting the expectations of their teachers. However, even though the participants were adequately meeting the expectations of their teachers (as evidenced by good grades) by following prescribed methods and procedures, they recognized their limited mathematical abilities. This is consistent with the findings of Boaler (1997), who discovered that the girls in her study were "less willing to relinquish their desire for understanding and play the 'school mathematics game'" (p. 6).

Girls begin to recognize that they do not possess the skills needed to call themselves "real" mathematicians, much in the same way that someone who bakes brownies from a box would not pronounce themselves a "real" cook. The qualities that distinguish "real" cooks from the "fake" cooks are much the same as the ones that distinguish a “real” mathematician from someone who can get an A in Algebra 1. “Real” cooks know how to select ingredients, how to anticipate the outcome of a dish and make changes mid-preparation, and knows how to improvise when required ingredients are unavailable. For example, if the brownie recipe calls for vegetable oil and you don’t have any in the house, do you know what to substitute? If the macaroni and cheese tastes bland, do you know what spices to add to enhance the flavor?

The current way that mathematics is taught in most schools today prevents students from learning the necessary skills they need to be “real” mathematicians. While they earn good grades (or can make boxed brownies), they realize their limited abilities and decide that their mathematical abilities are lacking. Early on in their mathematical careers they appreciated easy computational success by following scripted procedures, but later on realized their ability to problem solve, to improvise, to “season to taste” is quite limited. In order to acquire the skills of a “real” mathematician, one must be given opportunities to engage in “real” mathematics, not simply to make boxed brownies. For, when put in a situation where the box is no longer available, no real cooking can be done.

Similarly, the NCTM argues that an emphasis on making *connections* should be a priority in mathematics classrooms. For,

> Mathematics is a highly interconnected and cumulative subject. The mathematics curriculum therefore needs to introduce ideas in such a way that they build on one another. Instead of seeing mathematics as a set of disconnected topics, students should perceive the relationships among important mathematical ideas. As students build connections and skills, their understanding deepens and expands (NCTM, 2011)

However, the findings of this study indicate that mathematics continues to be taught as a series of disconnected topics, usually working independently. However, according to Gilligan (1982) women demonstrate a preference for “connected knowing” which values intuition, creativity, personal experience, and induction. In an environment that employs connected knowing, “authority derives from shared experiences, not from power or status. A creative process would be used to gain experiences from which conclusions could be drawn” (Becker, 1995, 167-168). This is contrasted with “separate knowing,” is characterized by an emphasis on logic, certainty, structure, and deduction. Becker makes the argument that a form of mathematics learning that requires strict obedience and rule-following, as was illustrated in the section above, is inconsistent with connected knowing.

Boaler & Greeno (2000) argue that girls “reject mathematics because the pedagogical practices with which they had to engage were incompatible with their conceptions of self” (p. 186). In particular, these girls identified themselves as “connected knowers” while traditional math pedagogies require students to be “received knowers” who “must surrender agency and thought to follow predetermined routines” (Boaler & Greeno, 2000, 171; Belenky, Clinchy, Goldberger, and Tarule, 1986). Ironically, “received knowers” are the ones most likely to choose mathematics as a major in college. However, they are promptly confronted with the reality that college level mathematics requires a great deal of creativity, intuition and problem-solving, skills more aligned with “connected knowing” (Boaler & Greeno, 2000, 171). This pattern was also found among the participants of this study, who either rejected the procedural way of learning in their high schools, or encountered great challenges when entering college and being asked to think creatively in math class for the first time. According to Becker (1995),

> Presenting mathematics in the 'commercial with (male) voice-over' mode, as disembodied knowledge that cannot be questioned works against connected knowing. The imitation model of teaching, in which the impeccable reasoning of the professor as to 'how a proof should be done' is presented to students for them to mimic, is not a particularly effective means of learning for women (p. 169).

Overall, this lack of connected teaching and learning encourages participants to view mathematics as a useless field of study. Similarly, being asked to repeatedly crack eggs for no apparent purpose will hardly motivate someone to want to continue "cooking." While a person might find cracking eggs fun or easy, but it is doubtful that she or he would continue egg cracking in the future without being made aware of how the skill was useful. Instead, an individual might become disinterested in cooking and begin to view it merely as an obligation.

Finally, a general lack of *support* in the mathematics classroom due to the emphasis on competition, independent work, and lack of differentiated instruction also contributed to these participants' disinterest in math. For,

> Effective teaching requires deciding what aspects of a task to highlight, how to organize and orchestrate the work of students, what questions to ask students having varied levels of expertise, and how to support students without taking over the process of thinking for them (NCTM, 2011)

However, this research provides evidence that few teachers possess the pedagogical content knowledge to be about to scaffold students' learning in such differentiated ways. Instead, students begin to perceive mathematics as a frustrating and independent endeavor, one that rarely provides opportunities for collaboration or joy. If when learning to cook, a person was prevented from collaborating with other cooks, sharing discoveries, or swapping recipes, learning to cook would be similarly alienating. After all, cooking with and for others is always more enjoyable than cooking alone.

SummerMath: Now We're Cooking!

As discussed in Chapter 6, the discourses present in the SummerMath program were vastly different from the ones participants described in their other mathematics classes. Most prominently, the SummerMath program provided a counter discourse to the way mathematics is traditionally taught. The SummerMath program valued process over product, emphasized problem solving and communication rather than memorization and procedure-following, and demonstrated the benefits of collaboration instead of competition. Mathematics was talked about and practiced in ways that highlighted the useful applications of the concepts they were learning, instead of isolated, irrelevant procedures. Multiple ways of knowing were valued, and all students were expected to contribute their unique perspectives.

In addition, the predominance of female teachers in the SummerMath program, along with the single-sex environment, resulted in a redefinition of who does mathematics. The presence of so many females who enjoyed and excelled at mathematics countered the sexuality and deviance discourses that currently exist. The participants were exposed to "normal" women with whom they could relate, which promoted a discourse of inclusion.

Success for every girl in the program was ensured through group work, meaningful individual feedback, and self-paced tasks. This discourse of math ability challenges the dominant discourse of math ability as innate or biologically based. Many of the participants entered the program with low confidence or little prior success in mathematics. However, with persistence and appropriate teaching practices, they witnessed the fact that their math ability could improve. With this experience, a new discourse of math ability as learned was created. This discourse is consistent with recommendations by the AAUW (2008) and Dweck (2008) to promote a "growth mindset." According to Dweck (2008), a growth mindset is one in which an individual views intelligence as changeable through effort. Dweck (2008) discovered that individuals who possessed a growth mindset were more persistent and less susceptible to a loss of confidence when experiencing challenges.

With this in mind, it makes sense that this study revealed three types of positive outcomes of the SummerMath program including: 1) problem solving skills, 2) persistence, and 3) confidence. In terms of problem solving skills, as a result of participating in the program, participants reported an increased ability to problem solve, and to explain their thinking about solving mathematical problems. They also explained that their ability to persist when solving difficult tasks was greatly improved. Finally, participants also asserted that attending the SummerMath program resulted in changes in the participants' confidence level and interest in mathematics. Survey results supported these qualitative findings, indicating that by the end of the program, the girls had higher levels of self-confidence in mathematics, as well as higher confidence in their ability to solve time consuming problems (see Table 6). In fact, all participants reported taking math classes beyond the required courses as a result of this increased confidence in their own math ability. This is consistent with a broad range of research that has provided strong evidence that single-sex environments can have positive effects on girls' confidence in their own math ability and their interest in mathematics overall (Haag, 1998; Lee & Bryk, 1986; Gwizdala & Steinback, 1990; Spielhofer, O'Donnell, Benton, Schagen, & Schagen, 2002; Stables, 1990; Mallam, 1993). Participants also reported improved post-program mathematics grades. While it is impossible to tell if the program had a direct impact on these participants' high school math grades, there is a clear pattern of improvement among these participants. This trend seems to suggest that the program at least had a modest positive effect on the students' academic performance in math.

Perhaps most significantly, the SummerMath program led to changes in the participants' perceptions of mathematics as a field. Participants were exposed to new ways of thinking about mathematics, new ways that math can be applied in the real world, and new mathematical careers. Exposure to these different areas of mathematics influenced several participants' selection of future course work. Participants acknowledged that their experiences in the SummerMath program broadened their ideas of the applications of mathematics. The courses they took explicitly showed them how math was connected to those fields of study. This emphasis on practical application resulted in participants seeing math as a "bigger umbrella" that encompasses more careers than just being a math teacher, and more skills than mere computation. Survey results indicated that the participants' belief in the usefulness of mathematics increased significantly from the beginning to the end of the program. This suggests that the SummerMath program had a short-term impact on the girls' ideas about how math could be useful in their lives. While only two of the nine participants have entered a math or science career, all participants reported a change in their perception of what mathematics is used for and what careers are available for those interested in the field. Overall, the SummerMath program resulted in participants liking and appreciating math as a subject much more than they had in the past.

However, there is less evidence to prove that the program had any long-term effect on their beliefs about the importance of math in society. As discussed in Chapter 5, only Grace and Harper, both engaged in math or science careers, see mathematics as being central or important in daily life. The rest of the participants saw mathematics as playing a very limited role in society, with the exception of its connection with the sciences. Even after attending the SummerMath program, these women had very limited ideas of mathematical careers and the usefulness of mathematics. In fact, several of the participants articulately explained how mathematical ability is not valued socially in the dominant culture. For this reason, few of them saw math ability as a powerful social resource. All of them recognized that taking math courses in high school and college were important for "opening doors" or "getting into college" but ultimately didn't see math ability as necessary for success in life. Therefore, it appears that the SummerMath program had little long-term influence on the participants' beliefs about the importance of mathematics in society.

So, even though SummerMath improved participants' problem solving skills, persistence, and confidence, most still did not pursue mathematical careers. Similarly, participants claimed that SummerMath helped them to see math as a "bigger umbrella" and more relevant, and that it exposed them to careers in mathematics. That may be true, however, ten years later when I asked them to list some jobs that mathematicians do, they had great difficulty identifying anything other than professors, teachers, or scientists. Participants also claimed they rarely use math in their daily lives. This suggests that SummerMath had only a limited impact on participants' long-term views of mathematics as a field of study.

As for the discourses that played the greatest role in these women's career decisions, it appears that the mathematics discourse was the most influential. For many of the participants, the traditional way that math was taught created a negative image of the field. Often mathematics was portrayed as useless or unrelated to real life. As a result, many participants had little interest in that field of study. In addition, participants had a very limited understanding of the types of mathematical careers that are available due to their minimal contact with mathematicians and limited discussion of mathematics in society. This creates a discourse of deviance, in which participants believe that only a few "nerdy" individuals "do math all day." The "mystique" of mathematics has led many of these participants to doubt their own ability to do "real" mathematics and discouraged them from entering mathematical careers.

Sexuality Discourse: Cook vs. Chef

In addition to providing additional empirical support that math continues to be taught in didactic and procedural ways, the findings of this study are also consistent with previous research reporting that girls report low levels of mathematics self-confidence, despite their success and proven ability in the subject (Catsambis, 1994). Similar studies have found that girls tend to assess their math ability lower than boys with the same math ability (Correll, 2004). Correll (2004) as cited in AAUW (2010) points out that "Boys do not pursue mathematical activities at higher rates than girls do because they are better at mathematics. They do so at least partially because they think they are better" (p. 44). An important part of a girl's career choice involves believing they have the ability to succeed in that career (AAUW, 2010). If a girl, due to stereotype threat or messages about male domination in mathematics, assesses her abilities lower than her male counterparts, she is going to be less likely to be interested in a career in the mathematics field. Women tend to hold themselves to a higher standard when assessing themselves in masculine domains, resulting in a tendency to underestimate ones' own mathematical ability (AAUW, 2010). Therefore, it is no surprise that the women in this study reported relatively low levels of confidence in mathematics despite their high academic performance in the math classes they took.

Similarly, even though women continue to do much of the cooking in the United States, many still don't consider themselves "real" cooks. Instead, the "real" cooks are the highly paid executive chefs of restaurants. However, 91% of chefs in the Bay Area are men and they get paid an average of 20% more than their female counterparts (Weiss, 2007). So, even in an arena that has been traditionally deemed female, women still hold few positions of power or prestige and often do not identify as "real" cooks. It is no surprise then, that in mathematics, a traditionally male dominated field, women would be reluctant to identify as "real" mathematicians. In many ways, the reasons for disidentification are the same. Both cooking and mathematics are often portrayed as merely about following scripted recipes or procedures. During much of the early learning process, women obediently follow recipes and mathematical procedures with success. They don't burn the brownies, and they get the correct answer. Nonetheless, they are still left feeling like they don't really know how to cook or do math because the tasks they know how to do require very little independent thought or creativity. This is in sharp contrast to mathematical jobs or the work of executive chefs, which require a great deal of those two attributes.

But that is not where the similarities end. Unfortunately, both early experiences with cooking and mathematics are deemed acceptable for women because they will provide her with basic skills to support her family. For women, cooking in the private sphere is deemed appropriate because it is “helping” and selfless, and ultimately benefits the family unit. On the other hand, women do not receive the same messages about cooking in the public sphere. Instead, becoming a chef is viewed as highly ambitious rather than selfless, for personal gain or profit rather than “helping”, and can take time away from family life. Women demonstrating an interest in mathematics are sent similar messages. A basic knowledge of mathematics is important, and perhaps even expected, for an educated mother will raise better educated children. However, an interest in a mathematics career challenges gender norms and calls women’s gender and sexuality into question. For, why would any normal women want to pursue a career as socially isolated as mathematics? Further, the pursuit of such an advanced degree, and the extended time commitment a mathematical career would demand simply would not allow a women adequate time to meet her family obligations.

Considering girls’ and women’s role in sport may also be a helpful parallel. In some ways, the messages girls receive about playing sports are similar to the ones sent about learning mathematics. Currently, many girls are encouraged to play sports for the health benefits. However, once women leave high school and enter college or professional sports, these messages begin to shift. Suddenly there is concern that the competition is too serious, and that training and competing take up too much of their time. Again, there appears the distinction between the public and the private realm. It is acceptable and expected that women will exercise in private, either at home or at the gym, but once their performances are for public viewing, it is no longer appropriate.

Clearly, the women in this study reported receiving gendered messages from their parents, peers, teachers, and the media about math ability and career expectations for women. They described feeling stigmatized if they expressed a strong interest in mathematics. Again, this finding is consistent with previous research literature that revealed that frequently, women with mathematics PhDs refuse to identify themselves as mathematicians and feel compelled to justify their career choice to others outside of mathematics (Murray, 2000; Damarin, 2008). Still, there is a significant body of research that suggests that women who were supported by small communities or families that valued math ability for girls can be insulated from the deviance discourse or the math ability discourse and be more likely to persist in math and science careers (Herzig, 2002). However, this study suggests that such a supportive familial connection is not always enough to encourage girls to pursue careers in mathematics. While both of the women who entered math or science careers came from families of mathematics, several other participants also came from similarly encouraging backgrounds. Those positive influences alone were not enough to lead them to mathematics careers, which suggests the process is far more complex than simply providing women with positive mathematics role models. Girls and women also need to feel that they belong in the field. Allexsaht-Snider & Hart (2001) define belonging as "the extent to which each student *senses* that she or he belongs as an important and active participant" in mathematics (p. 97). Herzig (2002) argues that students' involvement or integration into the communities of their departments is important for their persistence. If women don't feel they fit it or that the field of study is aligned with their personal identity, they will leave.

It does appear that the SummerMath program influenced the girls' beliefs about math ability being deviant or normal. As discussed in Chapter 5, participants recalled the significance of being surrounded by so many girls and women who enjoyed and excelled at mathematics. Several participants indicated that being able to form close relationships with women or girls "like them" was pivotal in their understanding of math ability. They suggested that getting to know mathematicians helped them to see mathematicians as "normal" and not socially isolated individuals. For girls like Grace, who already had a passionate interest in mathematics, being around so many other girls and women who shared her interest made her feel more "normal." Lastly, because it was expected that all girls would succeed in the SummerMath program, math ability was thus normalized in that setting. In other words, being mathematically able was something that everyone was capable of and expected to do, rather than an exception to the rule. The survey data also provides support that the SummerMath program resulted in statistically significant differences in their beliefs about math as a male domain (see Table 6). In other words, after the program, the girls were more likely to believe that girls belonged in mathematics. However, it is unclear from the participants' interviews whether those short-term improvements were translated into long-term changes in beliefs about women's role in mathematics. Despite these positive experiences, most of the participants saw few social benefits to being mathematically able. They insisted that math ability is not something that is valued in day-to-day social interactions, and excessive math ability might actually be a social disadvantage.

Unfortunately, there was only marginal evidence that the SummerMath program influenced the girls' career decisions. However, all of the participants indicated that the program influenced their future course selections. As they were exposed to new fields of study, such as architecture or computer programming, the participants became interested in taking those courses at their high schools, when previously they had not considered such fields of study. Or, an increased confidence in their own math ability resulted in students taking elective or advanced math courses in high school or college. For Amala and Ryan, taking these advanced math courses enabled them to pursue careers in medicine later on. For Rachel, taking the computer programming course at SummerMath was her first introduction to graphic design. She believes that being exposed to the field during the SummerMath program is what led her to pursue a career in graphic design. Grace, too, explained that the architecture course at SummerMath propelled her seek out a similar career. Upon entering college, Grace decided to major in engineering since architecture was not an option and she saw engineering as the most closely related field.

That being said, as discussed in Chapter 5, all of the participants interviewed expressed their desire to enter "helping" professions. These women have been socialized to believe that working for monetary gain is inappropriate and selfish. Because they view math as an isolated and individual endeavor, they see it as contradictory to a helping career. Similarly, the participants were keenly aware of the gendered discourse surrounding mathematics, and have been repeatedly told that boys and men are better at and more represented in mathematical fields. Upon entering upper level mathematics courses, these women were acutely aware of the disproportionate number of men in those classes. This sexuality discourse inevitably influenced these women's career choices, whether consciously or not.

From the research findings, it is unclear how the SummerMath program influenced the girls' interpretation of their gendered role in society. The participants were reluctant to acknowledge that gender played any role in their mathematical experiences or their career choices. In addition, while the women appreciated the single-sex environment, they provided little evidence that the experience changed how they saw themselves as women in society. Frequently, the participants attested that they did not feel intimidated by boys or men in their math classes, and did not recognize the predominance of boys in upper level classes as influencing their interest in mathematics as a career. These women have high aspirations and see few obstacles in their way to achieving their goals.

And while there is some evidence that attending SummerMath made them believe math ability is changeable and not innate, that it decreased their perceptions of math as a male domain, and normalized math ability for girls by introducing them to other girls and women who excelled at mathematics, it appears SummerMath did little to challenge the dominant sexuality discourse. Even if participants felt comfort in the single-sex environment of SummerMath, they couldn't articulate why and didn't acknowledge that gender played any role in their mathematical experiences. Interestingly, when I asked the program director about how she articulates to students why the program is single-sex, she admitted that they avoid talking about it. She argued that talking about male dominance in mathematics presents a proven stereotype threat for girls. In other words, if girls and women are told that men currently dominate mathematics, they will be more likely to believe they can't succeed in field. However, it is also possible ignoring this "truth" may be one reason women don't have language to articulate why single-sex education was significant to their experience. Not talking about male domination is a form of discourse. The fact that gender and sexuality are intentionally not discussed at SummerMath may be a reason why the program had only short-term impact on participants. They all enjoyed their single-sex experience but did not possess the language to explain why the single-sex environment was useful or how it was different from the rest of their mathematical experiences. This was a missed opportunity.

While the SummerMath program is an extremely powerful and positive experience for young women, these findings suggest that lack of explicit conversations about gender may be one reason its long-term effects are limited. If we want girls and women to challenge the status quo they must be made aware of their marginalized status in mathematics through consciousness raising. Otherwise, capable women like the ones in this study will continue to underestimate their own abilities, attribute their lack of interest or success to themselves, and will fail to see how the discourses of mathematics and sexuality are operating simultaneously. Girls need to be encouraged to ask why there are more boys in upper level math classes, what are the messages being sent, both implicitly and explicitly, and how are the experiences of girls and women different from those of boys and men. The single-sex environment of SummerMath is a perfect place to begin this conversation. However, without such consciousness raising, an unexamined single-sex experience many be perceived as a pleasant break from reality, rather than a vehicle for social change.

There is no doubt that SummerMath has the very best interests of its students in mind. However, denying girls the opportunity to give voice to their oppression because of fear of stereotype threat is misguided. Not talking about women's role in mathematics sends girls the message that their feelings of marginalization are not valid, or at least not a priority. It also teaches girls to remain silent in the face of oppression. Without these types of honest conversations and opportunities to identify and critically question shared experiences, women will continue to be underrepresented both as mathematicians and chefs.

Feminist Standpoint Theory Revisited

As a side note, feminist standpoint theory was a guiding principle of this research study. Damarin (1995), among others, suggest that women have less to lose and more to gain by challenging the status quo and are better able to criticize the field of mathematics because of their marginalized status. However, the findings of this study have propelled me to reconsider the legitimacy of such arguments. Below I will discuss both the strengths and weaknesses of feminist standpoint theory, and make an argument that without opportunities for consciousness raising, obtaining a feminist standpoint will not necessarily result in deeper critical analysis of the field of mathematics.

One of the more obvious strengths of feminist standpoint theory is the focus on listening closely to the voices and experiences of women. In addition, utilizing a feminist standpoint does have the promise of exposing divergent perspectives on a previously taken-for-granted phenomenon. For example, Hawkesworth (2006) suggests that feminist standpoint theory is relevant because the "systematic comparison of divergent “standpoints” illuminates the role of tacit assumptions in the selection of evidence, demonstrates questionable premises, and identifies grounds for assessing the credibility of particular claims” (p. 176). She also argues:

> Feminist scholarship has shifted over the past two decades from a notion of “the” feminist standpoint to a recognition of multiple feminist standpoints and multiple standpoints of women and men. As an analytical tool, feminist standpoint analysis accepts plurality as an inherent characteristic of the human condition and uses the comparison of multiple and competing views as a strategy for knowledge production (Hawkesworth, 2006, 177).

In this way, feminist standpoint theory does have the potential to generate inquiry that begins to address and examine the complexity of the social world.

Despite these strengths, feminist standpoint theory is not without its problems. First, the simple act of being marginalized does not automatically result in having a better perspective or improved ability to question the status quo. For, it must be recognized that women are also the products and reinforcers of these dominant discourses. Similarly, Pinnick (2008) identifies another problem with the theory:

> It is not possible to assert, with consistency, that men (or some other ‘culture’) have a systematically skewed view in science just because men are the dominant culture, and that women being a marginalized culture will have an improved view just because women are marginalized. The problem is that once feminist standpoint theory becomes the correct, or dominant, theory of science, then women are no longer marginalized and, hence, women lose any pretensions to the status of best-possible epistemic view (p. 1059).

In response to these criticisms, Hartsock (1998) attempts to clarify her support of feminist standpoint theory.

> I am not suggesting that oppression creates “better” people; on the contrary, the experience of domination and marginalization leaves many scars. Rather it is to note that marginalized groups are less likely to mistake themselves for the universal “man.” And to suggest that the experience of domination may provide the possibility of important new understandings of social life (Hartsock, 1998, 240).

We can assume women have different subjugated knowledges because of their different experiences and positionality. And diversifying the discourses available seems beneficial since different ways of knowing can lead to new ideas. However, their perspectives are not necessarily better. It is important for their voices and perspectives to be heard, but we cannot assume these subjugated knowledges are better simply because they are currently part of the non-dominant group. New perspectives can contribute a great deal, but those perspectives are not necessarily better. For example, one can look at a house from many different perspectives (i.e. inside or outside, from above or below, using sight, hearing, smell, or touch). Each of those perspectives might be "true" but one is not necessarily better than the others. The best way to get the most complete picture is to take all of those perspectives into account.

Another important problem with feminist standpoint theory is the assumption that all women have less to lose than men by challenging the status quo. This supposition assumes that all women share one type of femininity and that they experience patriarchy in similar ways. However, what we know is that some women may actually have a great deal to lose by challenging the status quo if they are more aligned with hegemonic femininity. In fact, it is likely that these women will not even see themselves as oppressed by gender.

In this way, women are not all the same and their perceptions of their gendered experience will differ, depending on their social, cultural, racial, and socioeconomic backgrounds. One of the dangers of adopting a feminist standpoint theory is essentializing women's experiences by paying attention only to the similarities among women, and overlooking the differences between them.

This is precisely the same criticism of the feminist movement that resulted in the emergence of a theory of intersectionality (Collins, 2000). Feminists were criticized for speaking universally for all women, but relying predominantly on the experiences of white, middle-class women. Much like the weaknesses of feminist standpoint theory, prior theories of gender failed to reflect the complexity of social life.

According to Collins (2000), intersectionality is an "analysis claiming that systems of race, social class, gender, sexuality, ethnicity, nation, and age form mutually constructing features of social organization, which shape Black women's experiences and, in turn, are shaped by Black women" (p. 299). Intersectionality is based upon the theory that an individual's social identities are mutually constitutive, meaning that one identity takes its meaning in relation to other identities (Shields, 2008). The formation and maintenance of those identities is then a dynamic process that the individual actively engages in (Collins, 2000). Thus, it makes sense that social identities will significantly influence a person's beliefs about and experience of gender. One of the strengths of intersectionality is that it:

> [R]eflects the reality of lives. The facts of our lives reveal that there is no single identity category that satisfactorily describes how we respond to our social environment or are responded to by others (Shields, 2008, 304).

Gender identity construction and maintenance is a complex task, one further complicated by the mutually constitutive nature of other social identities. As Shields (2008) explains,

> These intersectional identities are defined in relation to one another. That is, intersectional identities, as Spelman (1988) famously observed, are not a "pop bead metaphysics," that is, not a set of discrete identities like beads on a string, but, rather, they are relationally defined and emergent (as quoted in Shields, 2008, 303).

As discussed previously, women will experience gender in different ways, based on the various social identities, their social location, and historical specificity. For, "[e]ach individual derives varying amounts of penalty and privilege from the multiple systems of oppression which frame everyone's lives" (Collins, 2000, 287). Therefore, it is entirely possible that some women may not see themselves as oppressed by gender because they benefit from hegemonic femininity. Or, they may already see themselves as racially or socioeconomically oppressed and resist acknowledging further oppressions.

As a novice researcher designing my first major research project, I made a conscious decision to limit the number of variables I considered. With gender as the primary focus, this study intended to identify the shared experiences of a diverse group of women. And by focusing solely on gender, this study did provide valuable information about women's mathematical experiences. However, the next logical step would be to systematically examine the intersecting identities of race, gender, and class and how they influence how women experience the various discourses identified in this paper. Such an undertaking would require a much larger sample size, and one in which participants were purposefully selected to represent low, middle, and upper socioeconomic classes, along with varying races within those classes. Similarly, if I were to discuss the intersectionality of race and class with any validity, I would need to hear from the participants about the influences of those identities on their math experiences.

While there were several instances where participants spontaneously discussed those intersections, subsequent research that pays special attention to those intersections could provide valuable information about how the experiences of women differ across race and class. That being said, there is no doubt that race and class played important roles in these participants' gendered mathematical experiences, both in competing and complementary ways. For example, Grace's story of feeling like an "anomaly" because she was the only young, black, female accountants at her firm poignantly exposes how each of us is made up of not one, but numerous mutually constitutive social identities. Katelyn also shared her frustrations of attending a poor urban school and the role her white working class neighbors had on her perception of education and careers. Each of the participants in this study experience patriarchy in both similar and fundamentally different ways.

By offering this discussion of intersectionality, I am, in some ways, doing exactly what Shields (2008) warns against, which is "inserting a self-excusing paragraph that simultaneously acknowledges the central significance of intersectionality and absolves oneself of responsibility for attempting to incorporate it into the work" (p. 305). But, I also firmly believe that any research project, particularly a doctoral dissertation, is a learning experience. I do not regret my solitary focus on gender in this body of work, as I believe it has generated valuable information about women's experiences in mathematics. Nonetheless, I also realize that by making such a theoretical and methodological choice, only certain types of knowledge could be produced.

Conclusion

SummerMath effectively offers a powerful counter discourse to the dominant math discourse (D1). But in order for significant long-term changes to occur, interventions need to be more widespread and present at all developmental levels. Further, if the goal is to increase the number of girls and women interested in mathematics careers, the first step is to change the way math is currently taught.

Specifically, schools need to adopt practices similar to the ones employed in the SummerMath program. Students need to be given autonomy, and encouraged to become flexible and creative problem solvers. Math needs to be taught in connected ways so students can see its relevance and identify how the concepts they are learning impact their own lives. And finally, math students need to feel supported through the use of differentiated instruction, group work, and emphasis on process over product.

However, addressing the issues with mathematics education will not be enough to beckon girls to mathematics as long as the sexuality discourse remains unchanged. Currently, expected gender roles make mathematics appear incompatible with being a "good woman." That discourse will only change when girls and women *and* boys and men are encouraged to examine the taken-for-granted assumptions about sex and gender in our society through consciousness raising. Once the math discourse (D1) and sexuality discourse (D5) are changed, the ability (D2), power (D3), and deviance (D4) discourses, which are essentially by-products of the first two discourses, will inevitably become even less influential in girls' and women's decision to enter math careers.

The participants in this study were clearly marginalized in mathematics. As a result, they frequently felt alienated and frustrated, most leaving mathematics behind as quickly as they could. While they had many criticisms of the way math was taught to them, they had very little to say about how gender influenced their math experiences. Nonetheless, their perspectives, not often heard in educational research, offer unique information about the experiences of some women in mathematics. The findings of this study provide women with evidence that their experiences have been shared by many other women before them. That in itself is useful and empowering knowledge production.

While it is possible that by participating in this study, these women engaged in some form of consciousness raising around gender issues, it is unlikely that it occurred because they did not have the opportunity to engage in dialogue with other women to share their stories, identify themes, and strategize ways to overcome them. It is my contention that feminist standpoint theory is only valid if the participants have the chance to increase their consciousness about their own oppression. Otherwise, we are expecting a marginalized group to speak eloquently about their oppression without having the experience or vocabulary to do so. In some ways, assuming the feminist standpoint theory is correct is much like assuming that all single-sex learning environments will contribute to the deconstruction of gender roles. In fact, there have been many single-sex math interventions and most, while demonstrating impressive short-term results, have had limited long-term effects, much like SummerMath. This does not mean that these programs are lacking merit. Instead, it shows the importance of explicitly talking about gender oppression if an implicit goal of the program is to end it.

Overall, the SummerMath program offers a valuable opportunity to learn ways to incorporate feminist and reform-based pedagogy into mathematics classrooms, provide students with access to female mathematics role models, challenge gender stereotypes for careers, and increase girls' interest and enjoyment in mathematics. However, until these practices are incorporated into large-scale mathematics curriculum and pedagogy, and gender oppression is explicitly addressed, the long-term influences of such programs will be limited at best.

CHAPTER 8

IMPLICATIONS AND CONCLUSION

Overview of the Study

This qualitative study addressed a gap in previous research by exploring the long-term effects of a single-sex reform-based mathematics program on girls' career interests. In Chapter 1, a theoretical framework was presented to examine the issue of women's under-representation in mathematical careers and was used as a guide for the methodology. Five competing dominant discourses that play a significant role in women's decision to enter mathematical careers were discussed. They include: 1) mathematics, 2) ability, 3) power, 4) deviance, and 5) sexuality. While there are many other discourses that play a role in the lives of women, it is proposed that those five most directly influence women's decisions to enter the field of mathematics. Together, those discourses, in concert with the counter-discourses that are continuously emerging, create a complex web of messages about mathematics and gender that ultimately limit women's views of what careers are available and acceptable for them to pursue.

The literature review in Chapter 2 presented the research on the gender gap in mathematical careers, and research on the two primary reform movements in mathematics education that have been argued to improve girls' achievement and interest in mathematics: reform-based pedagogy and single-sex education. Because the two reforms have not been systematically studied together, there was a compelling rationale for a study of a single-sex math program that employs a reform-based pedagogy to examine the combination of the two reforms on girls' long-term career choices. Also, by learning from contexts where minority girls are succeeding and enjoying mathematics, and by listening to the lived experiences of girls' in mathematics classrooms, this study will help us better understand how to provide equitable and enjoyable mathematics learning experiences for all students (Stanic, 1989).

Chapter 3 provided an overview of the research study and the methods employed for data collection. Chapter 4 reported the quantitative findings of the study. Chapter 5 discussed the qualitative findings and explored how those findings expand upon the theoretical framework that was used to guide this study. Chapter 6 provided a discussion of those findings within the context of the research literature on this topic and revisited the research questions that were presented in Chapter 1. In this final chapter, the implications for practice and future research will be discussed.

Implications for Practice

One of the goals of this research was to add to the existing body of literature and to identify steps to be taken by administrators, policy makers, and researchers to make an impact in the mathematics field. This study identified specific changes that could be made by institutions to recruit and retain girls and women in mathematics. These suggestions are outlined below.

1. Create and utilize curriculum that emphasizes real-world connections, connections to previously learned mathematics topics, and connections to other subjects. The inability to make connections with the content being learned was the primary reason that the women cited for disliking mathematics. Providing students with opportunities to apply the mathematics they are learning to real-

world situations not only led to greater interest in math, but also more inclusive understanding of the uses of mathematics. This resulted in a greater appreciation for the role of mathematical ability in society. To emphasize real-world connections, schools could implement community service programs that require students to use mathematical skills to improve their local community. In addition, districts can adopt reform-based curricula such as the Connected Mathematics Program (CMP), which utilizes context-based problem solving for each concept being introduced. Finally, k-12 schools could make more of an effort to create cross-curricular units that highlight the applications of mathematics in other subjects. These recommendations are consistent with recommendations made by the National Council of Teachers of Mathematics, who argue that "School mathematics experiences at all levels should include opportunities to learn about mathematics by working on problems arising in contexts outside of mathematics. These connections can be to other subject areas and disciplines as well as to students' daily lives" (NCTM, 2000, 66). The AAUW (2010) also recommends "emphasizing real-life applications in early STEM courses" (p. 93). As discussed in Chapter 2, there is a great deal of empirical evidence that suggests that reform-based pedagogies that emphasize problem-solving and application of mathematical concepts result in not only greater overall achievement, but also increased equity across race, class, and gender (Boaler, 1997; Boaler, 2002; Riordan & Noyce, 2001).

2. Provide professional development opportunities for teachers that emphasize teaching for understanding and problem solving rather than memorization or procedural rule-following. Participants in the study expressed a clear preference for learning mathematics through problem solving. While they admitted that such a method is frequently more cognitively demanding for students, the women argued that the SummerMath program's emphasis on problem solving led to a deeper understanding of the material being taught. Engaging in true problem solving tasks, the girls saw themselves as active doers of mathematics, rather than passive receptacles of information. This active role resulted in greater engagement and interest in the field of mathematics. This shift in pedagogy will be a long and difficult process for teachers comfortable with traditional mathematics instruction. For, in order for teachers to teach mathematics in this way, they must have authentic experiences learning mathematics through problem solving themselves, so that they might begin to see the value in such a teaching methodology (Franke & Kazemi, 2001; NCTM, 1991). One of the criticisms the participants had of their mathematics teachers was their lack of pedagogical content knowledge and ability to make the material accessible to them. Teacher education programs must provide pre-service and in-service teachers with these types of professional development opportunities. In addition, student-teachers should be provided with opportunities to see teaching for problem-solving in action and gain experience using reform-based curricula. If no such opportunities exist, exposure to the curricula and opportunities to view videos of best practices

such as those offered by the Annenberg Media on www.Learner.org can serve as a valuable substitute.

3. Personalize the learning process in mathematics classrooms by providing more opportunities for students to use their creativity. Mathematics was perceived by participants as an extremely rigid, procedural, and impersonal field of study. Participants disliked math class because they felt they could not make a personal connection with the material being learned. They did not see how the concepts would be useful in their real lives, and did not see the work of mathematics as requiring any individual thought or creativity. English, science and social studies classes were greatly preferred because of opportunities to use their creativity to complete class projects. This is consistent with other research on creativity in mathematics, which called for more opportunities for pre-service and in-service teachers to explore and develop a greater understanding of how creativity might be incorporated into teaching and learning math (Bolden, Harries, & Newton, 2010; Shriki, 2010). A greater effort needs to be made to incorporate assignments and activities into mathematics learning that require students to think critically about tasks, and for which "personal touches" and creative approaches are valued and celebrated. Until that occurs, students will continue to see mathematics as "joyless," "boring," and "irrelevant."

4. Incorporate more opportunities for both boys and girls to form relationships with female roles models who excel at mathematics. Participants indicated that being

able to get to know women who liked and were good at mathematics influenced their beliefs about their own math ability. They reported having few female mathematics teachers in their careers, and felt that personally knowing a woman who was good at mathematics was extremely important in forming their ideas about mathematicians. An easy first step to achieving this would be to create more programs focused on introducing all students to female math mentors. Female mathematicians could be brought in as guest speakers, or students could go on field trips to meet women who use mathematics in their careers. Making female mathematicians more visible to students is a crucial step toward changing the gendered societal beliefs about who does mathematics. In addition, schools could make more of a commitment to hiring and retaining female math teachers and professors. For, it has been demonstrated that exposure to more female mathematicians can help reduce stereotype threat (Aronson, Fried & Good, 2002). In fact,

> Aronson suggested that one reason girls lose confidence as they advance in school stems from “the stereotyping that students are exposed to in school, the media, and even at home that portrays boys as more innately gifted and math as a gift rather than a developed skill. Without denying that biological factors may play a role in some math domains, psychology also plays a big role” (Aronson, 2010 as quoted in AAUW, 2010, 41).

Additionally, a repeated or long-term threat can eventually undermine mathematical aspirations through a process called “disidentification.” Aronson defines disidentification as “a defense to avoid the risk of being judged by a stereotype” (AAUW, 2010, 41). This stereotype threat can also lead to inaccurate self-assessment of girls’ own ability. When looking at students with equivalent past math achievement, Correll (2001) found that boys assessed their mathematical ability higher than girls, and were more likely to enroll in calculus classes than similarly achieving female peers simply because they believed that they were better at it. This is consistent with the findings in this study. Seven of the 9 girls reported low levels of confidence in their math ability, despite taking and succeeding in the majority of their math coursework. Overall, students need to believe they have the ability to excel at math or else they won't consider a career in mathematics. In addition, "Cultural beliefs about the appropriateness of one career choice over another can influence self-assessment and partially account for the disproportionately high numbers of men in the quantitative professions over and above measures of actual ability" (AAUW, 2010, 46). According to the AAUW (2010), one way to counteract these cultural beliefs or social discourses is to teach students about the successes of girls and women in math and science. For, the more girls and boys learn about women's achievements in mathematics, the harder it will be to believe that boys and men are better at math.

5. Incorporate mathematics career information into the k-12 curriculum. It is clear that students' lack knowledge about potential careers in mathematics beyond becoming a teacher or professor. Students have very limited understandings of what mathematicians do and the ways that mathematics is used in many different types of jobs. For this reason, students need to be exposed to careers that use mathematics (i.e. architecture, graphic design) through course offerings, guest speakers, mentor programs, and field trips. Schools could also consider creating internship programs that allow students to shadow individuals who use

mathematics in their work in order to gain a greater understanding of exciting careers in mathematics. Similar programs have been proven to be very successful at generating interest in math and science careers (Paulsen & Bransfield, 2009). For example, Plant, Baylor, Doerr & Rosenberg-Kima (2009) found that simply showing a 20 minute video about the lives of female engineers and the benefits of engineering careers to groups resulted in at least a short-term increase in their interest in engineering careers. Similarly, the results of this study are consistent with previous research that found there are clear gender differences in career aspirations. It is well documented that “women are more likely than men to prefer work with a clear social purpose” (AAUW, 2010, 22). And unfortunately, “most people do not view STEM occupations as directly benefiting society or individuals” (AAUW, 2010, 22). The women in this study wanted to be socially responsible and contribute directly to society, which is an admirable goal. But, in order to make math more appealing for women like them, we need to change the image of the math field to highlight ways math contributes to society. These social connections need to be made explicit at all levels in the mathematics curriculum.

6. Revise introductory college math courses to include exposure to the varied career options available for mathematics majors. As discussed above, students arrive at college with a preconceived notion of what mathematics is and how it is used, based on their limited experiences in k-12 mathematics classrooms. As a result, they have very little knowledge of potential opportunities in the math field. And,

unlike many majors that have introductory courses that are meant to both socialize students and introduce them to possible careers in their field of study, mathematics has no such introductory course. Instead, students take calculus, often for the second time, as their "introduction" to the mathematics major. This is similar to what Margolis & Fisher (2002) found in their study of computer science students. They argued that "computer science programs often focus on technical aspects of programming early in the curriculum and leave the broader applications for later." (AAUW, 2010, 60), and strongly recommended presenting broader applications of computer science in introductory courses. It seems clear that if the goal is to attract more students to math and science careers, an introductory or survey course needs to be created that educates students about the many possible areas of study and careers in mathematics. Such a course could include field observation experiences, an introduction to previously completed applied mathematics projects, a survey of various mathematical topics, readings on mathematical occupations, or guest lecturers. Students could be encouraged to interview mathematicians in the field to gain a greater understanding of the realities of their jobs or to engage in their own applied mathematics project. All of these experiences would result in a greater appreciation for math as a field of study, eliminate some of the "mystique" that surrounds math, and could propel new students to pursue a mathematics degree.

7. Modify existing single-sex mathematics programs to incorporate explicit discussion of gendered experiences and oppression. Opportunities for

consciousness raising must be provided if the full potential of single-sex environments is going to be realized.

Implications for Further Research

The purpose of this study was to add to and enhance the existing body of research on girls and women in mathematics. The study identified key areas of future research that may assist practitioners and policy makers in on-going efforts to close the gender gap in mathematical careers and improve the quality of mathematics education for all students.

First, further research should be conducted to examine the practices of families of mathematicians and encourage those practices in non-math families. The results of this study are consistent with prior research that suggests that girls raised by a parent with a math or science background are more likely to enter a math or science career herself (Herzig, 2002). Participants who came from math or science families all reported that their parents rarely answered questions for them, but instead required them to think critically or find answers for themselves. Those parents also valued problem solving and persistence. More research is needed to examine the specific practices of “math families” in an effort to learn which practices are most influential on girls’ interest in mathematical careers. If those practices can be identified, it is possible that programs can be developed to teach those practices to non-math parents and caregivers.

Secondly, more qualitative research is needed to explore the practices of school communities where math ability is an expectation for all students. While they are rare, there are schools in this country where math ability is the norm, not the exception. These schools currently operate in sharp opposition to the dominant discourse that says math ability is rare and innate. We need to learn from these successful programs about how to create a discourse of inclusion and high expectations surrounding math ability.

Third, there continues to be little research on the long term effects of reform-based pedagogy on students' career choices. Longitudinal studies comparing the impact of reform-based pedagogy on boys' and girls' career interests will provide a more complete picture of students' gendered mathematical experiences. It remains unclear whether reform-based pedagogy impacts both genders equally and this information will provide an important contribution to the current body of research on women's under-representation in mathematical careers.

Fourth, I would be interested in examining the impact an introductory math course, specifically designed to introduce students to the mathematics major and possible careers in the field, has on student retention and interest in mathematics careers. While there has been a good deal of research on introductory math courses like Math Excel that emphasize problem-solving, collaboration, and reform-based pedagogy (Duncan & Dick, 2000), there is a lack of empirical research on courses designed specifically to introduce students to possible mathematical careers. Since an introductory mathematics course is required at most colleges and universities, this form of intervention, while occurring late in students' mathematical careers, has the potential to reach a large audience. As discussed in Chapter 2, degrees in mathematics account for only 1% of all bachelor's degrees awarded each year (NSF, 2007). If a lack of understanding of mathematical careers and the social contributions of mathematical work are a significant reason why few people enter mathematics careers, such a course could greatly expand the pool of mathematical scholars by generating the interest of both men and women. A properly designed course has the potential to play a significant role in changing individuals' perceptions about the social usefulness of mathematics and could perhaps help improve the reputation of mathematics as a whole.

Fifth, this study could be replicated at other single-sex reform-based programs to substantiate these findings. Examining other similar programs would enable researchers to determine which characteristics are shared by the programs and whether or not they have similar outcomes. Interestingly, participants focused their discussion primarily on the reform-based pedagogy used in the program and had very little to say about the single-sex aspect of the program. This seems to indicate that reform-based pedagogy is more important to girls' mathematics experiences than a single-sex environment. More qualitative research needs to be conducted to determine the influences of each reform type and to learn from programs that are successfully engaging women and girls in mathematics.

Lastly, the women in this study were reluctant to acknowledge how societal gender roles influenced their interest in mathematics. Their lack of awareness of how gender has played a role in their experience is very revealing of the pervasive nature of the sexuality discourse and its entanglement with the discourse of mathematics. Presuming that single-sex environments will inherently promote gender consciousness is incorrect. Instead, it would be fruitful to investigate single-sex programs that explicitly address gender oppression and successfully engage in consciousness raising. Results may then be compared to studies of programs like this one to determine if such practices promote more interest in mathematics or other male dominated domains. If finding such consciousness raising groups proves difficult, conducting a similar study to the one presented here, but instead employing a focus group methodology could also be beneficial. For, such a methodology could provide a forum in which girls and women can examine their marginalized role within the mathematics field, presenting opportunities not only for consciousness raising, but also social change.

Conclusion

The goal of this research was to identify the key discourses that influence girls' and women's decision to enter mathematical careers. Despite efforts in recent years to increase women's participation in mathematical careers, the reasons for women's underrepresentation are still poorly understood. One explanation for this gap in the research literature is the absence of qualitative research studies that focus exclusively on women's experiences in mathematics. This in-depth qualitative study provided a unique contribution to the current body of research through its focus on listening closely to and learning from women's experiences in mathematics. Through the voices and experiences of this particular group of women, this study provides a more complete understanding of why so many girls and women reject mathematics as a potential career. This research highlights significant opportunities for changes in teaching practice that may result in a narrowing of the gender gap in mathematical careers as well as improve the quality of mathematics education for all students.

APPENDIX A

THEMATIC CODE FREQUENCIES

Discourse	**Code**	**Participants**								
		Amala	Catherine	Casey	Grace	Molly	Harper	Katelyn	Ryan	Rachel
Math										
	Obedience	x	x		x			x		x
	correct answers	x				x	x	x		
	non-creative			x		x		x	x	x
	no understanding			x	x				x	x
	Unconnected	x		x	x	x	x	x	x	x
	useless	x	x	x	x		x	x	x	x
	obligation	x				x		x	x	x
	Unsupported	x	x		x	x		x	x	x
	boredom		x	x	x	x				
	needs not met	x	x		x	x		x	x	x
	own pace		x			x	x	x		
	no group work	x	x	x		x		x	x	
	unapproachable	x		x		x	x	x	x	
	lack pedagogical content knowledge	x	x					x	x	
	surveillance	x		x		x	x			
	got harder	x	x		x	x	x		x	
	don't use math	x	x	x		x		x	x	x
Power										
	power	x			x		x			
	family of mathematics				x	x	x			
Ability										
	ability (innate, boys better than girls)	x	x	x	x		x	x	x	
Deviance										
	deviance	x	x	x	x	x	x	x		x
	messages about math	x	x	x	x	x	x	x	x	
	math careers			x	x				x	x
	mathematicians		x	x				x		x
	stigma	x	x	x		x	x			
Sexuality										
	sexuality	x			x		x	x	x	x
	want to help people	x	x	x			x	x	x	
SummerMath										
	Autonomy	x	x	x	x	x	x	x	x	x
	Connected	x	x	x				x	x	x
	Supported	x	x	x	x	x	x	x	x	x
	confidence		x	x				x	x	x
	persistence				x			x	x	x
	exposure to careers	x	x	x	x	x	x		x	x
	math ability		x	x		x		x	x	
	sexuality (single-sex)	x	x	x	x		x	x		

APPENDIX B

COMPARISON OF TRADITIONAL MATH AND SUMMERMATH

Traditional Math				**SummerMath**			
	What it looked like	**Outcomes**	**Perceptions of Math**		**What it looked like**	**Outcomes**	**Perceptions of Math**
Obedience (boxed brownies)	Memorization procedural Teacher as mathematical authority Student as passive Correct answers emphasized High grades/no understanding	No confidence No understanding Student dependency Give up easily No problem solving skills	Uncreative Impersonal Unmemorable	**Autonomy**	Critical thinking skills Problem-solving based Teacher as guide Student as active Process emphasized/no answers given Deep conceptual understanding of a few topics Creativity and intuition valued	Understanding Student independence Persistence Problem solving skills	Creative Multiple ways to solve Enjoyment
Unconnected (cracking eggs)	Separate knowing No connection to previous math No real world application	Disinterest Lack of effort	Useless Obligation	**Connected**	Connected knowing Context for every problem Real world application	Interest Intrinsic motivation High degree of effort	Useful Learning for personal advancement Bigger umbrella Introduction to math careers
Unsupported (cooking for one)	No differentiated instruction No group work Unapproach-able teacher Lacking PCK Surveillance	Frustration Anxiety Boredom Alienation Left math for good	Alienating Frustrating Anti-social	**Supported**	Differentiated instruction Single problem can take 2.5 hours or more Paired problem solving Approachable teacher	Success—improved grades Confidence Voice	Math ability can change Can be social

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