A MODEL OF ACADEMIC CHOICE FOR MATHEMATICALLY

TALENTED COLLEGE WOMEN

by

JUDITH LYNN GIEGER

(Under the direction of Dr. Jeremy Kilpatrick)

ABSTRACT

The goal of this study was to develop a model that described the factors that influence mathematically talented college women's choice of major. The study was motivated by the extensive research literature concerning the small number of mathematically talented women who choose an undergraduate major in mathematics as compared with mathematically talented men. In contrast to previous research, however, this study examined the academic motivations of talented women independent of the academic motivations of talented men, in an effort to avoid a "deficiency" approach to the analysis of women's academic choices.

Twelve mathematically talented college women from throughout the United States agreed to participate in a 12-week on-line focus group discussion via a Web site bulletin board. Nine of the participants were available for an individual interview after the close of the bulletin board. Data analysis followed the traditional qualitative method applied in grounded theory research: constant comparative analysis.

The resulting model of academic choice stated that the factors affecting the participants' choices could be expressed in four domains: environment, behavior, talent, and value. These domains are listed in order of relative importance, with environment having the lowest relative importance and value having the greatest relative importance. The relative importance of the domains refers specifically to how the participants responded to any conflict within the domain and the likelihood that a conflict would cause them to change their majors. When this model was applied to the specific question of why these women were choosing to major in or not major in mathematics, the data showed that the participants had very few conflicts or concerns with the environment of the mathematics departments at their universities. The participants had many conflicts and concerns, however, with the values of the mathematics departments at their universities, and those conflicts were often cited as a central reason (and occasionally the only reason) the participant was not majoring in mathematics. Specifically, many participants felt that it was important that their work have a positive, tangible social impact, and the abstract nature of mathematics was a cause of concern for them.

INDEX WORDS: Mathematical talent, College women, Undergraduate major, Mathematics, Online focus groups, Qualitative research, Academic choice

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JUDITH LYNN GIEGER

B.S., Millsaps College, 1990

M.A., Duke University, 1991

M.A.T., Duke University, 1993

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JUDITH LYNN GIEGER

Approved:

Major Professor: Jeremy Kilpatrick

Committee: Denise Mewborn
Nicholas Oppong
Bonnie Cramond
Martha Carr

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
The University of Georgia
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DEDICATION

To Pasha, Kolya, and Baby #2

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CHAPTER 1

THE PROBLEM AND ITS BACKGROUND

This is the story of twelve gifted undergraduate women and the issues they faced in choosing a major. All of them showed extraordinary mathematical talent and promise when they entered college, yet only a few chose to major in mathematics. Their conversations with each other and with me provided an informative look into how they came to make this important decision.

Background

Berryman (1983) was one of the first researchers in mathematics education to introduce the idea of a mathematics pipeline. All elementary students are in the pipeline, and throughout schooling, students leave the pipeline, resulting in a smaller and smaller pool of people from which future mathematical professionals will be drawn. A student’s ability to remain in the pipeline depends on three critical factors: opportunities to learn mathematics, achievement in mathematics, and the decision to pursue mathematics as a primary area of study. There is evidence that the gender gap has narrowed significantly for the first two factors: opportunity and achievement.

Mathematically talented male and female students are performing and participating at relatively equal levels throughout primary and secondary school (Arnold, 1995; College Board, 2001; Hanson, 1996), yet the large majority of undergraduate mathematics degrees are still awarded to men (Loftsgaarden, Maxwell, & Priestly, 2001). Therefore, not only are mathematically talented women leaving the mathematics pipeline during the college years, but there is evidence that they are leaving because of *choice* and not because of low achievement in their mathematics coursework (Oakes, 1990). Numerous intervention programs have attempted to address the issue of women's departure from undergraduate mathematics departments (Association for Women in Mathematics [AWM], 2002; Davenport, 1994), yet very few programs have addressed the issue from the perspective of women's choices. The assumption of many intervention programs is that if women are provided with opportunities to learn mathematics and support systems to encourage high achievement in mathematics the decision to remain in the mathematics pipeline will naturally follow (Miller & Silver, 1993). That, however, is often not the case.

In the 1990s, several research projects funded by organizations such as the Alfred P. Sloan Foundation, the National Science Foundation, and the Mathematical Association of America were undertaken to examine further the reasons that talented women were not choosing to study in undergraduate mathematics departments. The concern of these organizations is understandable given that the departure of talented women from the mathematics pipeline represents a considerable amount of "lost" talent and has implications in both academic and nonacademic fields. In nonacademic fields, jobs in areas of science, medicine, and technology are some of the most lucrative and prestigious careers available (Henrion, 1997), and remaining in the mathematics pipeline throughout one's college years is essential for these careers. Not only do these careers provide high income potential for women, but the existence of women and other minorities in these fields provides a diversity of viewpoints that can contribute to future innovations (Berryman, 1983; Oakes, 1990). Although the second half of the twentieth century has seen large increases in women's representation in these fields (Murray, 2000), inequities still exist. In 1996, women made up only 22 percent of this crucial labor force, and the average salary of a woman in a scientific or technical field was 16 percent less than that of a man in the same field (Bae & Smith, 1997).

The loss of women from undergraduate mathematics departments also has implications in academic fields in terms of the number of women who can potentially hold tenure-track positions in mathematics departments at American universities. In 2000, women represented only 22 percent of all full-time mathematics faculty, 17 percent of full-time doctoral mathematics faculty, and 14 percent of tenured full-time doctoral mathematics faculty. In the most prestigious Group 1 institutions, women represented only 9 percent of the tenured mathematics doctoral faculty (Loftsgaarden et al., 2001). These top institutions produce the lion's share of future mathematicians with the most political power, so the absence of women faculty in these departments may contribute to the myth that mathematics is a male domain (Henrion, 1997). This disparity in gender among mathematics faculty may also add to the sense that mathematics departments provide a chilly climate for undergraduate women (Luchins & Luchins, 1976). Without adequate role models in mathematics departments, mathematically talented young women may not see a place for themselves in the academic sphere.

The implications of this lost talent demonstrate the need for concern over the attrition of talented young women from mathematics departments during the undergraduate years. Unfortunately, the extensive efforts being made through research projects and intervention programs have had little impact on the problem. From 1992 to 2000, the percentage of female undergraduate majors steadily dropped from 44 percent to 41 percent (Loftsgaarden et al., 2001), the lowest percentage rate in a decade. This drop implies that mathematics educators, mathematics departments, researchers, and policymakers still have a great deal to learn, both in terms of theory and practice, about the issue of mathematically talented women's choice not to major in mathematics.

Rationale and Problem Statement

Stables (1996) indicated that subject area choice at the undergraduate level is the most significant factor influencing a person's opportunities later in life. The present study was motivated by a desire for a greater understanding of how mathematically talented young women make that choice. Although this issue has been addressed in the literature, previous studies on the topic of talented women's departure from the mathematics pipeline have a number of limitations. I attempted to overcome those limitations in formulating the research questions and design of this study.

The first limitation involves what is referred to as the "literature of difference" (Damarin, 1995, p. 246). Studies of mathematically talented female students and their academic choices have focused almost exclusively on male-female differences in mathematical talent. The predominance of male students in undergraduate mathematics departments is well documented (Loftsgaarden et al., 2001), so the often-unstated assumption in many of these studies has concerned the ways in which girls can be changed to be more like boys (Eccles, 1985). This assumption is hard to avoid when one group being studied already possesses the desired achievement outcome. Unfortunately, focusing on male-female differences does not necessarily shed much light on the potentially unique issues faced by mathematically talented women. Therefore, a greater understanding of how mathematically talented women make the decisions that they do calls for study of the women themselves and not just a comparison of them with men.

The second limitation involves restricting studies to only one subject area. Although the objects of interest in such studies are mathematically talented college women, limiting the group to women who have chosen or not chosen mathematics presents a dichotomy that may limit the findings of a study. When only women who have chosen mathematics are considered, it is tempting to simply describe personality and family characteristics and then make the conclusion that possession of these characteristics is all that is necessary to improve women's participation (Hanson, 1996; Henrion, 1997). Simply saying, "See, they can do it; you can too!" does not provide additional insight into what made them choose mathematics in the first place.

When only women who have left the mathematics pipeline are considered, the findings may be interpreted to be presenting their reasoning as deficient, given that they do not possess the desired outcome of choosing mathematics as a major. This deficiency approach may mask the positive motivations possessed by mathematically talented women who make legitimate choices to pursue other academic areas. It was important during this study to avoid asking a question such as, "Why aren't you doing math?" and instead to ask, "How did you make your choice?" The participants' answers to the latter question are used in this study to discuss why they did or did not choose to major in mathematics, but I used that information under the assumption that the choices that they made were rational, reasonable, and in no way deficient.

A third limitation deals with the theoretical approach. First, many previous studies have taken a unidimensional approach to the motivations affecting women's choices, focusing only on confidence, family characteristics, or interactions with teachers and not reporting on how those issues affect one another (Hanson, 1996). Second, previous studies have tended to be theory driven rather than data driven, meaning that there is often an attempt to fit the experiences of mathematically talented college women into preexisting models of choice. In contrast, I used grounded theory methodology, which states clearly that themes, categories, and the subsequent theory that describes their relationship cannot be decided at the onset but rather must arise from the data during the joint processes of data collection and analysis (Glaser & Strauss, 1967).

These limitations are not intended to imply that nothing has been learned about women's experiences in college-level mathematics courses. Previous research has given us a great deal of information about what women experience in these settings, but we do not necessarily understand how those experiences (as well as other undergraduate experiences) work together to impact their choice to remain in or depart from the mathematics pipeline (Fox, Brody, & Tobin, 1976; Hanson, 1996; Henrion, 1997). In this study, I attempted to link women's undergraduate experiences (in mathematics and other areas) with their choice of major, as that choice inevitably keeps them in, or removes them from, the mathematics pipeline. The goal of this study, therefore, was to develop a theoretical model that explained the choice-making behavior of mathematically talented college women when choosing their undergraduate major within the context of their entire undergraduate experience, not just their experience in an undergraduate mathematics department.

Research Questions

As indicated in the preceding section, one of the limitations of previous research has been the focus on single factors that influences women's choices about whether to major in or not major in mathematics. Calls for additional research point to the need to take a multidimensional rather than a unidimensional approach to talented women's choices (Eccles, 1989), but a simple list of factors that influence women's choices would not necessarily provide the information needed to fully understand these women's choices. While factors such as opportunity and achievement may in fact play a role in women's choices, these factors may carry relatively little weight in comparison to other previously undiscussed factors. This is particularly relevant to any attempt to design intervention programs intended to encourage talented women to choose an undergraduate major in mathematics, as programs that focus on factors with low relative influence on women's choices will likely have less success than programs that focus on factors with high relative influence on women's choices. Therefore, a goal of this study was to develop a model of academic choice that not only addresses the multiplicity of factors that influence talented women's choices but also discusses the relative power of those factors.

To that end, this study focused on the following central research question: *How do mathematically talented college women decide to continue or discontinue their pursuit of mathematics as a primary area of academic study, as indicated by choice of major?* The subquestions posed to address the multiplicity and relative power of the factors that influence this phenomenon were as follows:

1. What are the factors that influence mathematically talented college women's choice of major?
2. What is the relative importance of these factors?
3. How does the relative importance of these factors explain why mathematically talented women choose to major in or not to major in mathematics?

CHAPTER 2

RELEVANT LITERATURE

Defining and Identifying Mathematical Talent

Any attempt to discuss the experiences of mathematically talented college women must first address the definition and identification of mathematical talent. This is no simple task as there exist multiple perspectives on the meaning of mathematical talent as well as talent in general. In this review, these perspectives are discussed in three general categories: talent as measured ability, talent as developed expertise, and talent as application of knowledge.

Talent as Measured Ability

An essential assumption of the perspective of talent as measured ability is that mathematical talent is, at any given time, a fixed mental construct that can be at least measured or observed. Although definitions within this perspective may allow for changes in mathematical talent over time, they assume that mathematical talent is an individual characteristic, affected little if at all by environmental factors. The most narrow definition of mathematical talent under this perspective is that of Stanley (1991) and Benbow (1992), who measured mathematical ability through out-of-level tests (i.e., tests designed for older age groups), specifically the mathematics portion of the Scholastic Aptitude Test (now the Scholastic Assessment Test I), known as SAT-M. This use of out-of-level testing was the basis for selection to Benbow and Stanley's Study of Mathematically Precocious Youth (SMPY), a summer enrichment and acceleration program for mathematically talented adolescents. The participants in SMPY had all scored above 500 (with a possible score range of 200 to 800) on the SAT-M at the age of 13. The assumption was that this test would capture a student's natural mathematical reasoning ability because up to age 13 all students would have received essentially identical formal instruction in mathematics. Although Stanley and Benbow's limited definition of mathematical talent has come under some criticism (Gallagher, 1996), their definition has had a great impact both on the research literature in this area and on the access to a large number of summer enrichment programs for mathematically talented students (Stanley, 1991). Definitions of mathematical talent such as Stanley and Benbow's tend to measure what is often referred to as "schoolhouse giftedness" (Renzulli, 1976), or the ability to successfully complete mathematical exercises commonly associated with formal school activities, with little if any attention to solution methods or creativity.

Talent as Developed Expertise

The second perspective of mathematical talent is probably the most common. It addresses not just the natural mathematical inclinations a person has but also the acquisition and development of further mathematical talent later in life. This perspective places mathematical talent within the context of the environmental and psychological factors that contribute to its development. A central assumption is that mathematical talent is not innate but is developed over time. This perspective, however, does not assume that certain components of mathematical talent will not be observable or even measurable, but assumes simply that the existence of these components is not in and of itself sufficient for the development of mathematical talent. Some of the components observed in mathematically talented schoolchildren include the ability for rapid and broad generalizations, the ability to curtail the reasoning process, flexibility in mathematical information processing, rapid reversibility of the mathematical reasoning process, and striving for clarity and economy in mathematical solutions (Krutetskii, 1976). Some components observed in mathematically talented adults include the importance of the unconscious and the intuitive in the creative mathematical process (Hadamard, 1945), the ability to learn and study independently (Bloom, 1985), and the successful intersection of analytical, creative and practical mathematical thinking (Sternberg, 1996). Although many of these abilities may be present in talented people in any field, it is the combination of these abilities with achievement and interest in the specific field of mathematics that leads to the person’s desire to develop his or her talent in mathematics.

Talent as Application

The consideration of talent as the application of knowledge is a relatively new perspective, and there are no specific studies of how it applies to mathematical talent. However, the characteristics behind the perspective of talent as the application of knowledge can be used to discuss how a person might make use of his or her mathematical talent. These characteristics are sometimes referred to as *evaluative skills* (Bloom, 1985), and they provide a link between the development of talent and the appropriate use of that talent. Sternberg (2000) refers to this perspective as *wisdom*, which he defines as “the application of tacit knowledge as mediated by values toward the goal of achieving a common good” (p. 253). This goal is achieved by balancing multiple interests (intrapersonal, interpersonal, and extrapersonal) among responses to environmental contexts. The perspective of talent as knowledge application does not eliminate the need to discuss the development of mathematical talent in terms of practical, analytical, and creative talent, but it places a goal of the common good as central to the individual’s need and desire to develop his or her mathematical talent in these ways. Sternberg points out, however, that this perspective of talent has received little attention in formal education.

This study used all three perspectives of mathematical talent to varying degrees. First, many of the participants had attended summer programs based on Stanley and Benbow’s model of talent identification and pointed to that experience as one of the first moments at which they had begun to see themselves as mathematically talented. This single criterion, however, was not broad enough for selecting participants, so I chose to build selection criteria around the ideas behind talent as developed expertise. As the study progressed, it became clear to me that the participants were concerned with the positive use of their talent, and thus the perspective of mathematical talent in this study evolved to consider talent as application.

The Underrepresentation of Mathematically Talented Undergraduate Women in Mathematics Departments

Much of the research on girls and women in mathematics has focused on the precollege years, with particular emphasis on middle school and high school. These years have been viewed as the time at which many young women begin to lose confidence in their mathematical ability despite the fact that girls tend to outperform boys at mathematical tasks in the early grades (Davenport, 1994; Sadker & Sadker, 1994). This loss of confidence leads to lower participation and achievement in mathematics courses in the middle school and high school years, and thus young women enter college less prepared than young men to study the advanced mathematics courses that serve as a critical filter for employment in lucrative scientific and technological careers (Chipman & Thomas, 1985).

The gap between female students and male students in achievement and participation at the precollege level, however, has decreased markedly over the last decade. In a report of the course-taking patterns of college-bound high school seniors in 1988 (College Board, 1988), of the students who had taken four or more years of mathematics, only 43 percent were female. Of those students who claimed to have taken honors courses in mathematics, 49 percent were female. Only 18 percent of the seniors took calculus, and only 44 percent of those students were female. In contrast, the report of college-bound seniors in 1998 (College Board, 1998) indicated that female students constituted 50 percent of those who reported studying mathematics for four years or more and 54 percent of those who reported having taken honors courses in mathematics. In addition, the percentage of college-bound seniors who took calculus had grown to 25 percent in 1998, and 51 percent of those students were female. These numbers indicate that young women are leaving high school as well prepared as, if not better prepared than, their male counterparts to study mathematics at the college level.

A look at mathematics participation and achievement in college presents a less balanced picture. Consider again the data on female students' participation in advanced mathematics among college-bound seniors in 1998. Despite the female students' level of academic preparation, only 45 percent of those seniors who planned to major in mathematics were female. Even more interesting is that after two years of college, only 41 percent of those students actually majoring in mathematics as juniors in 2000 were female (Loftsgaarden et al., 2001). Although the populations sampled for these two reports were not identical, the numbers indicate that fewer female students than male students plan to major in mathematics in college and even fewer relative to male students actually choose mathematics as their major. The first phenomenon reflects young women's perceptions of undergraduate mathematics before they enter college, and the second reflects how those perceptions change once they are in college. The former has received considerable attention in the research literature (Henrion, 1997; Oakes, 1990), whereas the latter has received much less (Seymour & Hewitt, 1997), despite the fact that both phenomena contribute to the relatively low number of female undergraduates in mathematics departments. A fuller understanding of the problem of the underrepresentation of female majors in mathematics requires research that addresses the factors contributing to initial attraction to the major and to retention once in the major.

Factors Influencing Mathematically Talented Women's Choice of Major

The research on talented women's achievement and persistence in mathematics falls into three categories according to the factors studied: the individual perspective, the environmental perspective, and the interactionist perspective. Studies that take the individual perspective generally focus on internal factors of ability, self-confidence, value, and causal attributions. Studies that take the environmental perspective generally emphasize external factors of classroom interaction (student-student and teacher-student) and social support. The interactionist perspective combines both internal and external factors and often presents causal models of their respective impact on women's achievement-related choices.

Individual Factors

Ability. The research on individual factors assumes that barriers to talented women's achievement in mathematics lie within the individual. Although some researchers argue that women are deficient in mathematics ability, other researchers put less emphasis on ability than on the psychological and motivational factors that affect women's choices (Eccles, 1985). Benbow and Stanley (1980, 1983) have been strong advocates of a physiological and biological explanation for the difference in participation rates between mathematically talented young men and mathematically talented young women. They discount the effect of other factors such as differential course taking on women's representation in college-level mathematics courses:

> It is notable that we observed sizable sex differences in mathematical reasoning ability in seventh-grade students. Until that grade, boys and girls have presumably had essentially the same amount of formal training in mathematics. Thus, the sex differences in mathematical reasoning ability we found were observed before boys and girls started to differ significantly in the number and types of courses taken. It is therefore obvious that differential course-taking in mathematics cannot alone explain the sex difference we observed. Instead, it is more likely that

> mathematical reasoning ability influenced subsequent differential course-taking in mathematics. (Benbow & Stanley, 1980, p. 1263)

Benbow and Stanley believe that biological factors explain most gender differences in mathematical reasoning, and hence mathematical participation, although their critics contend that Benbow and Stanley have not provided biological data to support their view (Gallagher, 1996).

Self-confidence. As an alternative to explaining differences in mathematics participation in terms of ability, most recent research on individual factors has focused on motivation. One motivational factor is confidence in one's own abilities. Mathematical ability is still taken as a factor in this research, but *ability* is interpreted as the student's subjective perception of his or her own ability and not as a measurement against some objective external criterion. Fennema and Sherman (1977) found that of all the affective variables they studied, self-confidence was the most strongly correlated with mathematics achievement. In addition, they found gender differences in confidence even when there were no differences in achievement. Female students who performed as well as male students tended to report lower self-confidence.

Discussing the self-confidence of gifted college women, Heller and Ziegler (1996) cite several sources indicating that gifted women have a less favorable self-concept than their male peers despite the high academic performance of both groups. Similar results were found in a longitudinal of high school valedictorians and salutatorians (Arnold, 1995). Upon entering college, equal proportions (20 percent) of men and women among these top-performing students considered themselves to be far above average in intelligence. By their sophomore year, however, only 4 percent of the women, compared with 22 percent of the men, still thought of themselves that way. This drop in self-confidence took place even though the women had received grades that were as high as those of the men in the first year of college.

Task value. Another motivational factor that has been shown to affect talented women's persistence in mathematical activities is *task value*. It can be defined in multiple ways, such as attainment value, interest, utility, and cost (Eccles, 1983; Pintrich & Schunk, 1996). These multiple definitions are used to distinguish between the value of an activity to meet goals, whether immediate or future, and its value for more aesthetic purposes. Although in general, girls tend to attach less attainment value and utility to the study of mathematics than boys do (Eccles, 1983; Stanic & Hart, 1995), that difference has not been as readily demonstrated among the gifted population (Csikszentmihalyi, Rathunde, & Whalen, 1993; Li & Adamson, 1995).

Equally inconclusive results have been found for interest in mathematics. Although some researchers have found that mathematically gifted girls find mathematics less aesthetically interesting than mathematically gifted boys do (Benbow & Stanley, 1980; Heller & Ziegler, 1996; Ryckman & Peckham, 1987b), others indicate that mathematically gifted girls and boys find mathematics equally low in aesthetic interest relative to other subjects (Csikszentmihalyi et al., 1993; Li & Adamson, 1995).

Benbow and Lubinski (1993) focused on the cost of giving up other academic and social activities as a result of intensive mathematical studies. They concluded that mathematically talented girls tend to be more socially and aesthetically oriented (in contrast to an orientation toward theory and utility among mathematically gifted boys) and are therefore less willing to sacrifice aesthetic value, social needs, and desires for the utility gained through advanced mathematical study. Another cost consideration involves one's perception of the sex-role appropriateness of the task. A mathematically talented girl may have a high level of interest in mathematical activity, but she may be unwilling to pursue it because of the potential cost to her gender identity (Ryckman & Peckham, 1987b).

Causal attributions. A great deal of research has been devoted to the impact of causal attributions on mathematics achievement and participation. Weiner (1979) proposed three dimensions along which an individual can attribute the success or failure of an event: stability (stable or unstable), control (controllable or uncontrollable), and locus (internal or external). Weiner also proposed that certain attributional dimensions have a greater effect than others on expectations for future success at an activity. For example, if individuals attribute their success to ability (a supposedly uncontrollable, stable, and internal attribution), then they are likely to expect repeated success at similar activities. On the other hand, if they attribute that success to luck (a supposedly uncontrollable, unstable, and external attribution), then they are unlikely to expect future success in a similar activity.

Bempechat, Nakkula, Wu, and Ginsburg (1996) found a positive relationship between mathematics achievement and ability attributions, but they did not examine the relationship between mathematics achievement and effort attributions. Ryckman and Peckham (1987a, 1987b) found that boys tend to attribute their academic success to ability and their academic failure to lack of effort, whereas girls tend to attribute their academic success to luck and their academic failure to lack of ability. The attribution of success to luck and failure to lack of ability can lead to a condition called *learned helplessness* (Ryckman & Peckham, 1987b), in which individuals begin to believe that they have little control over their own success or failure. This negative attributional pattern has also been found among the mathematically gifted population (Dweck, 1986; Li & Adamson, 1995; Ryckman & Peckham, 1987a), although there is a greater tendency among mathematically gifted girls to attribute their success to effort than to luck (Cramer & Oshima, 1992). Although these findings suggest that talented girls may experience relatively low levels of learned helplessness, some researchers have proposed that gifted girls' effort attributions have less impact on their future success than gifted boys' ability attributions do (Dweck, 1986; Li & Adamson, 1995). These studies do not make clear why effort attributions by talented girls are less predictive of future success than talented boys' ability attributions, given that effort attributions indicate a high level of control over outcomes (Weiner, 1979).

Environmental Factors

Classroom interactions. Considerable discussion concerning the interactions between students and their instructors has suggested that female students (both at the primary and secondary level) tend to have fewer interactions with their teachers than male students do, and that those interactions tend to be less encouraging than those between teachers and their male students (Sadker & Sadker, 1994). Additionally, commentators have suggested that female students are shortchanged in the way their teachers acknowledged them; that is, they are not called on as frequently as male students are, their responses are less frequently expanded on by teachers, and teachers ask them fewer questions (American Association of University Women, 1992).

Although less is known about teacher-student interactions in college, and specifically in mathematics and science courses, there is evidence to suggest that women majoring in mathematics or science have more negative classroom experiences than women in other fields. In a study of over 300 mathematically talented college women at the University of Michigan (Frazier-Kouassi et al., 1992), 36 percent of the participants recalled having had a personal discriminatory experience in their mathematics and science classes, in comparison with only 14 percent of those in other fields. Examples included students feeling that the professor put women down, patronized women, or ignored them. Participants also reported events where they felt that the professor did not take women seriously, did not respect their ability, or in some way conveyed that women were less able than men intellectually. Even in cases where such outwardly discriminatory behavior was not reported, subtle factors such as professors knowing the names of more male students than female students often had an impact on whether these talented women felt comfortable participating in classroom discussions.

The interactions between students in college mathematics and science classrooms also affect whether women are comfortable and confident. First, college mathematics and science classrooms are seen as more competitive and less cooperative. Frazier-Kouassi et al. (1992) reported that 45 percent of the women surveyed said that mathematics and science classes were too competitive and aggressive, and 35 percent cited that as a reason they were strongly discouraged about majoring in a mathematical or scientific field. Keith (1988) argues that a learning atmosphere that is more cooperative than competitive would result in more students, both male and female, continuing in mathematical and scientific fields. This assertion, however, does not take into account the gendered atmosphere of classroom interactions, even in a cooperative setting. Seymour (1995) found that collegiate academic situations that called for collaborative effort often produced great strain between female students and male students. Women noted that their male peers commonly did not know how to relate to them as colleagues, study partners, or even friends. Women in the sciences, in particular, expressed frustration that some male peers refused to respond to them in terms other than sexual interest. Given that many male students in the sciences overtly expressed the belief that all women in their discipline were, by virtue of their having chosen it, inherently unattractive, this rejection left little basis on which male students and female students could form a collaborative learning partnership.

Social support. There is evidence to suggest that female college students in the sciences receive less social support outside the classroom, from both professors and peers, than their male counterparts do (Seymour, 1995). Stake and Noonan (1985) reported on the positive impact a female teacher's academic interest had on a female student's achievement and confidence; yet given the small number of female faculty members in mathematics and science departments, the opportunities for such mentoring relations for college women in mathematics and sciences are few (Gavin, 1996). The difficulties cited above between female students and their male professors in science and mathematics classrooms suggest that any out-of-classroom mentoring relationship would be equally strained. Even in the case of highly mathematically talented women, male professors may be less likely to take them under their wing for fear that these women will eventually leave the field because of family and social concerns (Henrion, 1997). Talented women, however, cite the lack of effective mentoring as one of the reasons they choose to leave mathematics and the sciences in the first place (Seymour, 1995).

The impact of same-sex or opposite-sex friends on women's academic choices has also received some research attention, although the findings are somewhat contradictory. Fox et al. (1976) and Kanter (1977) found that women are more likely to make a nontraditional academic and career choice when a reasonable number of other women are present as classmates and colleagues. In contrast, Frazier-Kouassi et al. (1992) found that some women are strongly motivated by their minority status and seek to prove their academic competence in a collegiate atmosphere that is not necessarily welcoming or supportive. Although the findings of these studies are different, they indicate that the influence of classmates and colleagues, both same-sex and opposite-sex, affects women's choices.

Interaction of Factors

Although much of the research on college women in mathematics and science has focused on single factors such as classroom dynamics or self-confidence, most researchers accept that these women's choices represent the intersection of many different factors, both individual and environmental. This is certainly the case with the findings of the present study, as the participants in this study pointed to both external factors (such as the environment of their major departments and the expected behaviors within those departments) and internal factors (such as their perception of their own mathematical talent and their beliefs as to whether the development of that talent would be worthwhile) as affecting their choice of major. This study does not stand alone, however, as previous research has also examined the relationship between individual and environmental factors and their combined effect on women's achievement related choices. Three lines of work in particular demonstrate how these factors might interact for gifted and talented women in their choice of whether or not to pursue a mathematical or scientific field.

In a landmark study for the Alfred P. Sloan Foundation on the attrition of talented college students from science, mathematics, and engineering fields (abbreviated SME), Seymour & Hewitt (1997) surveyed over 350 SME students from seven U. S. colleges and universities to determine the factors that contributed to the students' choice of whether to remain in or leave their SME major. Contrary to previous findings concerning talented women's perceptions of their mathematical and scientific abilities, Seymour and Hewitt found that relatively few "switchers" left (9.8 percent) or considered leaving (11.5 percent) because they had discovered that a non-SME discipline was more suited to their abilities, and there was no gender difference in this regard. The predominant factors in talented college women's decision to switch from an SME major to a non-SME major were the view that a non-SME major offered a better education (46 percent), a lack of or loss of interest in SME (43 percent), the rejection of SME careers and associated lifestyles (38 percent), and the perception of poor teaching by SME faculty (33 percent). Although the empirical evidence provided in the report is impressive in its breadth and depth, Seymour and Hewitt did little to analyze possible causal relationships between the factors that led talented female students to “switch.” The primary value of the report lies in the contradiction between the empirical evidence it provides and many previous theories concerning the relative importance of personality factors in talented women’s academic decisions.

In contrast, Reis (1998) provided a causal model outlining the relationship between various personal and environmental factors and the realization of talent in women. According to Reis, the following four factors defined that realization of talent: (a) above average ability or special talents; (b) personality traits such as determination, motivation, patience, creativity, and risk taking; (c) environmental factors such as family and peer support opportunities; and (d) the perceived social importance of the use of or manifestation of the talent. Each of these factors helped the adult women in Reis’s study believe in themselves and promoted their desire to develop their talent regardless of field. Reis’s approach differs significantly from that of Seymour and Hewitt (1997) in that Reis did not assume that the factors would be any different for women who were choosing to develop their talent in mathematics than for those who were choosing to develop their talent in another fields, including nonacademic areas such as athletics or social causes. Unlike Seymour and Hewitt (1997), however, Reis did not provide any discussion of the relative importance of the factors she identified. Reis also provided little systematic empirical evidence to support her hypothesis.

The third line of work on talented women's choices, and the one that most strongly influenced the present study, was pursued by Eccles (1983, 1985, 1989). Her results show that there are two direct causes of a woman's intention to study mathematics further: her expectations for success at mathematical activities and the importance or value she attaches to mathematical activities. Eccles's choice model links a woman's achievement-related beliefs, outcomes, and goals to her causal attributional patterns, to the input of socializers (particularly parents and teachers), to her gender role beliefs, to her self-perception, and to her perception of the task itself. Each of the factors is assumed to influence both the expectations she holds for future success and the value she attaches to the activity. These expectations and values are then assumed to influence the choices that she makes among the many options that are available to her. Although both expectation and values are found to influence women's choices, Eccles (1989) stresses that the student's valuation of mathematics is somewhat more strongly related than her expectation of success to the decision to enroll in future mathematics courses. This finding is particularly relevant when Eccles's model is applied to gifted women, who tend to have a high level of expectation of success and high positive self-concept (Hoge & Renzulli, 1993). Therefore, Eccles (1989) suggests specific interventions that focus on addressing young women's valuation of mathematics rather than on confidence-building and motivation exercises.

Attempts at Intervention and Retention

Many programs have been designed to encourage talented women and girls to pursue degrees and careers in mathematics and science. Efforts began as early as the late 1970s and early 1980s and were built upon research suggesting that the attitudes and beliefs that girls brought to the study of mathematics kept them from going forward in the discipline (Fennema, 1976). A complete list of programs, past and present, would be too vast to include in its entirety. These programs range from national to local in scope, public to private in source of funding, and one day to several years in length. As an alternative to an exhaustive listing of all programs, regardless of quality or success, the Association for Women in Mathematics (AWM, 2002) provides a sampling of current programs at their Web site that they claim have been particularly effective at addressing the issue of the underrepresentation of women and girls in mathematics- and science-related courses and activities. The AWM listing also provides links to Web sites with further information about the programs.

Many of the programs are designed to intervene at the precollege level, particularly the middle school years. These programs include the following (with full citations for each included in the references):

- Expanding Your Horizons in Science and Mathematics (EYH) offers a series of one-day conferences for junior high and high school students at over 100 locations across the United States. The EYH program was initiated at Mills College in Oakland, California, in 1976, and over 550,000 young girls have attended EYH conferences since their inception. The conferences are designed to nurture girls' interest in science and mathematics courses and to encourage them to consider science- and mathematics-based career options. A typical conference day includes a keynote address as well as two workshops: one to provide hands-on learning activities and the other to provide opportunities to meet and talk with female role models in the fields.

- The St. Mary's College Paula Program for Young Female Scholars in Notre Dame, Indiana, provides participants with up to three one-week summer sessions on computers, mathematics and science, and the visual and performing arts. Designed for gifted and talented girls who will be entering grades 7 to10, this enrichment program combines instruction with cultural and laboratory experiences designed to stimulate and reinforce enthusiasm for learning.
- SummerMath at Mt. Holyoke College in South Hadley, Massachusetts is a four-week program for high school girls of all mathematical abilities. Introduced in 1982, the program is designed to help girls become better problem solvers, build their confidence in mathematics, and see how mathematical concepts apply to the real world.
- Sonia Kovalevsky High School Math Days, sponsored by the Association for Women in Mathematics, have taken place at colleges and universities throughout the

United States every year since 1985. The programs consist of workshops, talks, and problem-solving competitions for women students. The purposes are to encourage young women to continue their study of mathematics and to assist them with the sometimes difficult transition between high school and college mathematics.

Each of these programs shares the common purposes of building the mathematical confidence of talented young women and providing them with encouragement and information about careers in mathematics and science. In addition, all of the above programs are enrichment programs, either through summer academies or one-day conferences during the school year. These programs are representative of the many other programs throughout the country designed to encourage young girls in mathematics (AWM, 2002). Unfortunately, even such landmark programs as those listed above have yielded little if any evidence concerning their effectiveness in reaching their goals.

Programs designed for undergraduate women in mathematics tend to present a wider scope of activities than those available at the precollege level. Although some summer enrichment programs are available at the college level, mentor programs and research opportunities are also part of the attempt to attract and retain talented women in mathematical and scientific fields. Such programs include the following (with full citations for each included in the references):

- Summer Mathematics Program for Women Undergraduates (SMPWU) at St. Olaf and Carleton Colleges is funded by the National Science Foundation. This program is designed to encourage and support women in their study of mathematics. Its goals include introducing students to new areas of mathematics, honing their mathematical skills, building their confidence in their mathematical abilities, encouraging their enthusiasm for mathematics, and providing a supportive network of other female mathematicians. Admission to this program is highly selective and is limited to female mathematics students who are currently completing their first or second year of college.
- The Summer Program for Undergraduate Women in Mathematics (SPWM) at George Washington University is a five-week intensive program for mathematically talented undergraduate women who are completing their junior year and may be contemplating graduate study in mathematics. The goals of the program are to communicate an enthusiasm for mathematics, to develop research skills, to cultivate mathematical self-confidence and independence, and to promote success in graduate school. A total of 16 women are selected for the program each year.
- Research Experiences for Undergraduates, sponsored by the National Science Foundation, is a nationwide program that gives undergraduates the opportunity to participate in research projects in all areas of science, including mathematics. Students are granted stipends and in some cases assistance with housing and travel.

Although the program is not limited to female students, groups traditionally underrepresented in the sciences are particularly urged to apply.

- The Association for Women in Mathematics Mentor Network has as its goal to match mentors, both men and women, with girls and women who are interested in mathematics or in pursuing careers in mathematics. The program is designed to link mentors with a variety of groups, including recent doctoral recipients, graduate students, and undergraduates.

Like the programs designed for the precollege years, these programs have the common goals of encouragement, confidence building, opportunity, and support. Unfortunately, also like the precollege programs, there is little evidence (other than anecdotal) to demonstrate their effectiveness (Davis, 1991). Although the design of all of these programs (both precollege and postsecondary) is supported by the research literature, there is no corresponding longitudinal support for their effectiveness in reaching their goals.

Limitations of Previous Research and Calls for Additional Research

As mentioned in the first chapter, the three elements that contribute to a student's ability to remain in the mathematics and science pipeline are achievement, opportunity, and choice. Efforts to promote interest in mathematics among women and girls have focused largely on the first two elements (Davenport, 1994). The narrowing gap between male students and female students in mathematics course participation and mathematics achievement at the secondary level suggests that these strategies appear to be working. However, attempts at the college level to attract women to and retain them in mathematics majors have been less successful, in large part because of a lack of attention to the strongly contextual and value-laden issue of choice (Oakes, 1990).

Consider, for example, the Eureka program, which operated at Brooklyn College in the fall of 1988 (Miller & Silver, 1993). Fifty-three freshman women who had expressed interest in majoring in mathematics and science were recruited into the program, whose goal was to provide these women with the academic support system necessary for them to persist in mathematics- and science-related majors. By the end of their junior year, the group had decreased from 53 to 20, and only 6 of those 20 remained in mathematics- or science-related majors throughout the program. The goals and design of the Eureka program were strongly grounded in the research literature on women in mathematics and science, yet the program was by most measures unsuccessful. An important lesson Miller and Silver drew from the failure of the Eureka program was that “intervention programs . . . do not take place in a vacuum” (p. 24). The Eureka program did not adequately take into account the complex personal and societal factors that affected these women’s choices beyond the factors of achievement and opportunity. In short, “providing resources and support services does not necessarily mean that students will take advantage of them” (p. 27). A stronger focus on women's choices at the college level is necessary if researchers are to explore more fully why women leave the mathematics and science pipeline in the first place and if educators are to design effective programs to help discourage them from doing so.

Eccles (1985) also points to choice as being the essential element missing in most discussions of differences in mathematics achievement and persistence between mathematically able men and mathematically able women. By focusing on choice rather than ability, Eccles avoids the theoretical trap of always viewing the girls as the problem (Campbell, 1995).

> Conceptualizing sex differences in achievement patterns in terms of choice takes one beyond the question of "Why aren't gifted women more like gifted men?" to the question "Why do gifted women and men make the choices that they do?" Asking this latter question, in turn, legitimizes the choices of both gifted men and women and suggests several new variables as possible mediators of the sex differences we observe in gifted individuals' achievement patterns. By legitimizing the choices of both men and women, we can look at sex differences from a choice perspective rather than a deficit perspective. (Eccles, 1985, p. 265)

Eccles, however, recognizes that even while her research attempts to legitimize the choices of both gifted men and gifted women, her choice model (which arose from a comparison of gifted men's and gifted women's choices) still heavily favors the choices of men because their achievement-related choices in terms of mathematics and science are traditionally viewed as the standard. She also notes that there is little qualitative information concerning the achievement related choices of either gifted men or gifted women. Given the opportunities that qualitative research provides in terms of developing new theory (Creswell, 1998; Merriam, 1998; Patton, 1990), a qualitative study of women's achievement-related choices that does not compare them with the choices of men seems to provide fertile ground for describing, understanding, and ultimately legitimizing those choices.

CHAPTER 3

METHODOLOGY AND RESEARCH DESIGN

According to Creswell (1998), the central reason for choosing any qualitative research design is because "theories are not available to explain behavior of participants or their population of study" (p. 17). Grounded theory methodology is motivated by a similar yet more specific goal: to fill in the theoretical gaps left by a priori theories that do not necessarily fit the situation or do not work when applied to the situation. "By 'fit' we mean that categories must be readily (not forcibly) applicable to and indicated by the data under study; by 'work' we mean that they must be meaningfully relevant to and be able to explain the behavior under study" (Glaser & Strauss, 1967, p. 3). A research design that incorporates grounded theory methodology offered considerable potential for generating a theoretical model of choice that both fits and works for the population of mathematically talented college women. I attempted to be sensitive to these issues of fit and work not just in the reporting of results but also in the choice of methods and research design.

Participants

The theoretical sampling necessary for grounded theory research required that the participants represent a homogeneous group whose common experiences could contribute to the evolving theory (Corbin & Strauss, 1990; Creswell, 1998). For this study, the group was generally defined as mathematically talented college women, but a more specific definition was required in order to obtain the necessary homogeneity in age and mathematical experience.

A obvious selection criterion was that all participants should be mathematically talented, but, as described in chapter 2, this term is problematic. Was mathematical talent to be defined in terms of measured ability or interest or intensive practice? For the purposes of this study, a definition of mathematical talent that follows a talent development model was deemed most useful for the selection of participants. Theories of talent development (Bloom, 1984; Schneider, 1993) employ both ability and interest, and they view the combination of these factors as resulting in exceptional adult performance in a field. To that end, potential participants were eligible for the study if they met at least three of the following criteria for exceptional performance: (1) participation in extra-curricular mathematical activities, such as a math club or math team; (2) participation in a summer academic program for talented mathematicians; (3) consistently high grades in all four years of secondary mathematics; (4) a score of either 4 or 5 on the Advanced Placement Calculus AB or Calculus BC exam; (5) a score of 700 or above on any of the SAT II Mathematics exams; and (6) an exemption from a college mathematics course because of placement testing. In addition, the participants were given the opportunity to describe any other feature of their mathematical experience that they believed addressed their interest and ability in mathematical activities. The participants mentioned such events as taking college mathematics courses while in high school, teaching assistantships for college-level mathematics courses, industry internships, research assistantships, and college and high school mathematics awards. The qualifications for each participant covered a wide range of exceptional mathematical experience, encompassing the components of demonstrated mathematical ability, interest, and intensive practice.

Another obvious criterion for selection was that the participants had to be college-aged women who had declared their major. Initially, my intention was that all participants would be sophomores or above. This grade-level requirement was based on my assumption that many first-year college students have yet to choose their major and are still taking many of the required core courses at their university. By the sophomore year, most students have decided on a major and are enrolling in elective courses in their major. However, this assumption did not take into account the fact that many talented college students have been exempted from a large number of introductory college courses (either through AP credits or through joint secondary/college enrollment) and are therefore already taking elective courses in their major during their first year of college. Using new information from potential participants, I decided to open up the grade-level criterion to include any college-aged woman who had already declared her major and was taking elective courses in that major.

I gained access to the participants through the use of a network selection process called *snowball sampling* (Patton, 1990, p. 176). I began by contacting a former student of mine, Elizabeth (a pseudonym). As a middle school student, Elizabeth had taken my Algebra I class at an accelerated mathematics program for gifted students through the Duke University Talent Identification Program (TIP). During her first university year, she had informed me that she was "dropping" her mathematics major (her phrasing) in order to pursue a more applied field, biochemistry. Given the mathematical promise that she had shown as a young student and her subsequent decision to leave the academic field of mathematics, I felt that she would be an ideal participant for the study. I had renewed contact with Elizabeth during her first university year, so the personal connection and rapport necessary to this kind of selection process (Creswell, 1998) had already been established.

Once Elizabeth had agreed to participate in the study, she forwarded the proposal to other mathematically talented college women (at her own university and others) who she thought might be interested in participating. Each new potential participant also passed on the names of a few interested individuals, which resulted in a network of 24 potential participants. I sent potential participant an informal description of the project, including the purpose, rationale, and an description of what would be required of her if she decided to participate (see Appendix A). Potential participants were also asked to complete a brief biographical questionnaire (Appendix B). In order to expedite the process, all contacts, proposals, and questionnaires were sent through electronic mail.

After reflecting on some of the positive and negative experiences of participating in online discussions such as these, I realized that 24 participants would be too large to manage effectively. I therefore decided to reduce the total participants to 12. This decision was motivated by a desire to keep the participants' reading and writing load to a reasonable level so that conversation would be more easily facilitated. According to Gaiser (1997), as the number of participants in an online focus group rises, the participants have a greater chance of reducing their connection to and responsibility for the group discussion. This decision was also motivated by my plans for analysis. The data were to be analyzed on a group basis and tested on an individual basis, and 24 individual test cases seemed too large for this study. Using the biographical questionnaires, I selected 12 women who as a group represented a wide range of colleges, ages, and majors and individually best met the essential criterion of exceptional mathematical experience, looking particularly for a balance between traditional measures of mathematical ability and interest in mathematical activities. The data in Table 1 represent the participants' responses to the biographical questionnaire.

Table 1

Pseudonym, Age, Academic Major, and Selection Criteria of the 12 Participants

Name	**Age**	**Primary major**	**Secondary Major**	**Minor**	**Selection Criteria** (see p. 38-39)
GROUP 1					
Rachel	18	History and Science			1, 2, 3, 4, 5, other
Emily	19	Eighteenth Century European History			1, 3, 4, 5, 6, other
Jane	19	Environmental Engineering (previously Physics)	Art		1, 3, 4, 5, 6
Esther	20	Civil Engineering (previously Physics, then Electrical Engineering)			1, 2, 3, 4, 5, 6
Maude	21	Philosophy		Pre-med concentration	1, 3, 4, 6, other
Nan	21	Mathematics		Italian Studies	1, 3, 4, other
GROUP 2					
Clara	18	Mathematics			1, 2, 3, 4, 5
Knox	19	Bioengineering			1, 2, 3, 4, 5, 6
Elizabeth	20	Biochemistry (previously Mathematics)			1, 2, 3, 4, 5, 6, other
Lola	21	Mathematics	Visual Arts		1, 3, 5, other
Hadley	21	Engineering (previously Mathematics)	Mathematics Education		1, 3, 5, other
Katherine	21	Mathematics	Psychology		1, 3, 5, 6, other

Not surprisingly, the snowball selection process resulted in a group of participants who were not very racially diverse (10 white, 2 Asian), as the potential participants were recommending friends and colleagues who came from similar backgrounds to theirs. Despite this lack of racial diversity, however, the group did come from a wide variety of colleges and universities (1 large public technical university, 1 large private technical university, 3 moderate-sized private universities, and 1 small liberal arts private college, all coed) located throughout the United States (1 school in the Southeast, 1 school in the Southwest, 1 school on the Pacific Coast, and 3 schools in the Northeast). The participants also came from a wide variety of academic majors (see Table 1), regions of residence (5 from the Southeast, 1 from the Southwest, 4 from the Northeast, and 2 from the Pacific Coast), and types of secondary school backgrounds (6 attended public schools, 4 attended co-educational private day schools, and 2 attended single-sex private day schools).

As I mentioned above, all of the participants met at least three of the criteria for exceptional mathematical experience. However, an additional participant characteristic arose not out of the criteria for selection but rather from the selection process itself: self-identification. The use of a network selection process meant that I did not contact colleges and universities to find which students met these criteria and then recruit those students for the study. Rather, potential participants were given the informal proposal by a friend, and they contacted me if they were interested. The informal proposal did not outline the specific criteria for exceptional mathematical experience. The proposal only stated that I was looking for mathematically talented college women. Therefore, every potential participant, to some degree, perceived herself as mathematically talented. The specific selection criteria came only after she had already selected herself as belong to the group of mathematically talented college women. How and why the participants perceived themselves as mathematically talented is an issue worthy of further discussion and is addressed in chapter 4.

Data Collection

I collected data through focus group interviews (using an online bulletin board), individual electronic mail correspondence, and an individual closing interview (either in person or by telephone). This combination of data collection methods allowed me to compare what the participants wrote to the group, what they wrote to me individually, and what they said spontaneously in an interview setting.

Online Focus Groups and Electronic Mail

The online discussion took place over a 12-week period during the 2000 university spring semester. I asked the participants to log on to an online bulletin board a minimum of twice a week for the duration of the study, at least once to respond to a question posted by me and at least once to respond to another participant's response. Each participant used a pseudonym of her own choosing in her group postings. I also asked each participant to check her electronic mail a minimum of twice a week in order to respond to any specific questions that I needed to ask her, such as asking for clarification of a comment she made on the bulletin board.

Most of the data in this phase of the study were gathered through the bulletin board, not electronic mail, because the research design required that the participants respond to the group conversation and not just to me as the group moderator. Postings to the bulletin board took on a conversational rather than a question-and-response tone, which in turn meant that the bulletin board conversations served their own clarifying purpose. If a participant made a confusing or interesting comment on the bulletin board, the other members of the group often addressed the issues themselves rather than relying on me to lead the discussion. Because I began to take on the role of observer more than moderator or facilitator, individual electronic messages between me and the participants were seldom required.

I created the discussion site using the Bulletin Board feature of WebCT (n.d.). WebCT makes use of topic strands and a nested response system, which enabled the participants to move easily from one strand to the other. This feature meant that they were able to respond to any posting at any time during the duration of the online portion of the study. Strands were never “closed,” although some earlier topic strands did become “saturated,” meaning that the conversation on a strand came to a natural close as the participants felt that they had discussed the topic thoroughly. Once a strand appeared to be approaching saturation, I provided a summary of themes and categories that I saw emerging in the strand. Participants then came back to the strand to provide feedback on whether they thought those summaries were accurate. Their responses to the summaries were not made in isolation, however, as the participants were often judging the accuracy of the summaries in light of discussions going on in later strands. This nonlinear approach to posting responses on the bulletin board resulted in an online conversation that could be traced and analyzed both by the natural flow of the conversation and by the date and time on which postings were made. (See Appendix C for an example of the order and flow of conversation in the first strand.)

The design of the bulletin board included multiple strands of topics that reflected the proposed categories in the expectancy-value model of choice (Eccles, 1985) discussed in chapter 2. Each strand began with a single question designed to elicit discussion on that topic. As the need arose, either I or the participants posted additional questions on the bulletin board (or, occasionally, through individual e-mail). The ongoing discussion was the driving force for the new questions and new topic strands generated on the bulletin board, but the categories and topics in Eccles's choice model also played an influential role. I added a new topic strand to the bulletin board approximately every 2-3 weeks during the 12-week online discussion. (See Appendix D for a listing of the strands, the topics that they covered, and sample questions posed by both me and the participants.)

In an additional move to keep the group size and reading load for the participants manageable, I assigned the participants to two separate bulletin boards (6 members each) operating simultaneously. This decision also allowed for the possibility that topics and lines of conversation might arise in the two groups independently, adding strength to the finding that such an issue was essential and important to the participants' choices. Assignment to the two groups was not random but purposeful (Patton, 1990). I wanted to have two groups that were as diverse as possible in age, college affiliation, and major.

Because of the nature of the network selection process, several participants knew each other well and might possibly have recognized their friends despite the pseudonyms. Therefore, some participants were placed in separate groups to protect their anonymity. Each participant was able to access only the discussion board for her assigned group. The groups were not operating entirely independently, however, as I would often take topics of interest from one group and post them as follow-up questions in the other group. Also, some lines of discussion arose naturally out of both groups.

Because of the geographic dispersion of the participants, using the Internet to conduct the focus groups was ideal. However, the benefits of conducting focus groups online go far beyond the issue of distance. First, whether online or not, group interviews allow participants to provide their own perspectives while still interacting with others who have a shared experience (Krueger & Casey, 2000; Morgan, 1988). This interaction may help avoid anomalistic responses to researchers' questions. Groups also allow for the possibility of fine-tuning definitions and arriving at group consensus. However, one of the larger costs of participating in focus group research is the loss of anonymity. Fortunately, conducting these focus groups online meant that participants were able to maintain their privacy while still participating in a group discussion.

Additional benefits arose from the choice to conduct focus groups online. The first of these benefits was low cost. Software packages that allow simple design of bulletin boards and chat rooms, such as WebCT, are available free at most universities.

Also, no travel expenses were incurred, either by me or the participants. In addition, all participants had free access to the Internet and electronic mail through their colleges and universities. The second benefit was the use of a familiar setting. Although the literature on qualitative research emphasizes the use of naturalistic, nonlaboratory settings (Lincoln & Guba, 1985), the "virtual" setting of the Internet provided many of the same benefits of traditional field studies (Hine, 2000; Wood & Smith, 2000). The participants were all quite familiar with how to use the Internet as a communication tool, as they indicated on their biographical questionnaires. Therefore, no extra time was necessary for them to adapt to the setting. The third benefit was the minimization of time constraints. The participants could log on any time they wished, and they could use any location with Internet access (their dorm room, the library, their parents' house, etc.) to access the group discussion.

There was good reason to use bulletin boards rather than another form of group Internet communication, the chat room. Chat rooms, in their formal sense, require that all discussion group members log onto the site at the same time, which meant that the benefit of time flexibility would be lost. Also, chat rooms do not follow the same rules of etiquette in written language as electronic mail and bulletin boards (Cherney, 1999). Although many of the standard rules of grammar and punctuation are often abandoned in electronic communication, bulletin boards and electronic mail allow more time for well thought-out responses, rather than the immediate reaction required in a chat room.

Lines of discussion in a chat room may be hard to follow, as the response to a statement does not necessarily come automatically after the statement. The Internet allows for multiple lines of simultaneous conversation, but chat rooms still rely on a linear presentation, and therefore the discussion can sometimes seemed jumbled. All in all, the benefits of using an electronic bulletin board made it the best choice for collecting data in this study.

Of course, no data collection technique comes without its disadvantages. As I mentioned above, the standard disadvantage of focus groups (loss of anonymity) did not apply in this study, but anonymity itself can be its own disadvantage. Being anonymous in a conversation can result in a lower level of responsibility for what is said. What someone is willing to say to another person over an anonymous bulletin board and what he or she is willing to say when face to face with that person may be completely different (Wood & Smith, 2001). In this case, anonymity was certainly more of a advantage than a disadvantage, but it could easily have become a distraction had a conversation become rude. Along those same lines, the lack of face-to-face contact meant that the unspoken elements of conversation (body language, inflection, etc.) were lost (Cherney, 1999). Intent and inflection are very difficult to get across online. Thus, conversational etiquette must follow a different set of rules. Given the relative newness of online communication tools, these rules are still being developed (Wood & Smith, 2001). Therefore, misunderstandings and miscommunications could possibly have occurred. However, the fact that these women were familiar with the technology meant that they were comfortable with the rudimentary symbols and shorthand used to communicate effectively online. Thus, several risks of miscommunication were avoided.

One final disadvantage associated with online focus group research is that the physical and visual separation can reduce the level of participation or even increase the likelihood that a participant might drop out of the study (Gaiser, 1997). Although someone would not likely get up and leave the room during a face-to-face group interview, it is quite easy not to sign on to the bulletin board if one is pressed for time. I knew that minimal participation would be an issue in this study because of the participants' heavy academic schedules. Although the rate of response slowed somewhat at certain times of the semester, particularly around midterms, finals, and spring break, I was pleased that the overall participation level maintained a steady pace. Only two participants were unable to complete the online portion of the study—one because of illness, and the other because she was awarded a prestigious scholarship to study abroad and lost regular access to the Internet when she left the States.

Interviews

In addition to the data collected in the online portion of the study, I conducted a single closing interview with the nine available participants. The two participants who discontinued participation during the online discussion (Lola and Clara) were unavailable, and one additional participant (Knox) was unavailable because of her summer job. Six interviews were conducted over the phone, and three were in person. All interviews took place within one month of the completion of the online discussion group. Each interview took approximately one hour and followed a semi-structured interview format (Patton, 1990).

I developed the interview protocol directly from topics discussed on the bulletin board. I compiled a comprehensive list of questions based on the data already in hand from the online portion of the study and then before each participant's interview tailored the list to focus on topics relevant to her. Therefore, the semi-structured interview protocol used in the interview reflected both a cross-case and individual case analysis of the data. (See Appendix E for the comprehensive interview protocol.)

As I mentioned above, the use of a bulletin board rather than a chat room for the online portion of the study meant that the participants' responses to each other were presumably more reflective and less impulsive. Although this method of data collection had many advantages (as described previously), one cannot ignore the potential value of a spontaneous response given in a one-on-one interview setting. Thus, one of the main purposes of the interview was to allow for the possible inclusion of previously excluded data. Individual interviews allow for comments that may not occur in a group discussion, regardless of the medium, because of intimidation or politeness. According to Michell (1999), any research that uses focus groups runs the risk of disenfranchising individuals, and the combination of focus groups and individual interviews is a method that is sensitive to this risk.

Data Analysis

The process of data analysis in this study followed the traditional method applied in grounded theory research: constant comparative analysis (Corbin & Strauss, 1990; Creswell, 1998; Glaser & Strauss, 1967). An essential feature of the method is that data collection and data analysis are interrelated, often simultaneous, events. The method allowed for categories, codes and related questions to emerge from the data, at which point these questions were taken back to the participants for further discussion in the form of follow-up questions posted on the Web site. Categories were developed, discussed, and explored in an interative fashion (gather data from participants, analyze the data, return to the participants for more data, etc.) until the categories were "saturated," meaning that the participants felt that the discussion on a particular topic had run it's course and they had said all they wanted to say on the issue. It was this method of ongoing data analysis that helped guide the formation of questions and summaries for the bulletin board and the closing interview as described in the preceding section.

The initial open coding and analysis used during the data collection were relatively informal, utilizing mostly notes in margins and comments in my research journal. After data collection was complete, however, I continued open coding in a more formal way, creating a list of approximately 40 codes with references to data to which the individual codes applied. The exact number of codes resulting from this phase of analysis is truly approximate, as the codes and categories were constantly changing as I continued to test the codes against the data. The primary changes that occurred to the code "list" in this stage of analysis were the elimination of codes that appeared in an initial reading of the data but were not supported by the data in later readings. For example, references to *school size*, while appearing in a limited way in the first reading, did not have enough quantitative or qualitative grounding in the data to support its use in further levels of analysis.

An essential component of the data analysis was my attempt to allow previously unconsidered categories to emerge and to abandon previously considered categories that were not represented in the data. Therefore, the expectancy-value model discussed above needed to be as flexible as possible, given that the theoretical model at the end of the study needed to reflect categories grounded in the data, not categories assumed to exist from the onset. This requirement was particularly important for me to remember as I moved into the next phase of the coding process.

According to the techniques of grounded theory, additional levels of coding and theorizing take place after the initial open coding process. I used axial coding to take the initial categories from the open coding phase and assemble them in a logical fashion.

The purpose of this stage of analysis was to identify a central phenomenon and to explore causal conditions, strategies, and intervening conditions that affected it. Initially, I used this level of coding to organize my open codes based on the components of the expectancy/value model, but I soon found that this model was not adequately describing the conditions and factors that affected the participants' choices. In particular, the expectancy/value model did not account for the fact that while many factors affected the participants' choices, not all of these factors carried the same weight in the decision process. Simply put, some factors were more important than others. For example, the code *positive social impact in career* (which related to value) had a much stronger quantitative and qualitative grounding than the code *grades* (which related to expectancy), and the organization of the codes into categories needed to reflect this finding.

Also at this stage of analysis, certain codes were collapsed into single codes, such as *zone experiences* and *enjoyment* being combined into the single code *passion.* Other codes, such as *influence of parents* and *balancing family and career* were eliminated altogether. The data supported the existence of these codes in the initial open coding process, but the data did not indicate that these issues directly affected the participants' choices, and they were therefore removed.

After axial coding, I used selective coding to integrate the categories that emerged from the axial coding into a "story line" that would outline a conditional proposition or theory. I assembled four core categories and their subcategories into a model that described the relative importance of a variety of factors that influenced the participants' choices about their majors. Some of the initial codes were combined and others abandoned, as indicated previously, but this decision was made based on the need to include only the factors that the participants claimed influenced their choice of majors. The four central categories and their subcategories therefore represent the result of the collapsing, combining, and elimination of codes throughout the analysis process. Although the labeling of the central factors was my own (as a result of the analysis) and not a direct phrasing by the participants, the data supported the use of the terms.

It is worth pointing out that the coding levels and data analysis techniques associated with grounded theory are exactly that—techniques. They are not a checklist of prescribed steps that one must follow in the research process (Glaser, 1992), hence it is often difficult to say exactly at what point one phase of analysis ended and the other began. Open, axial, and selective coding are not strict procedures and do not in and of themselves produce theory. Rather, they represent techniques that I employed in order to assist in the difficult transition from data to theory. Therefore, the results of the data analysis process reported in chapter 4 are intended to signify the sensitivity of the theory to the data rather than just a reduction of the data to a list of codes and categories.

Researcher Expectations

I became interested in the issues discussed in this study for two essential reasons. First, I had taught mathematically talented young women for seven years through the Duke University Talent Identification Program (TIP), and my experiences with these young women had led me to question some of the traditional findings about this population in the research literature. My students were rising eighth graders at the time that they took my course, and their talent, confidence, and social development at such an early age made quite an impression on me. Although these talented girls did not, at such a young age, have much choice as to the path that their academic careers would take, they were nevertheless thinking about their futures. Despite their apparent mathematical talent and confidence in their talent, hardly any of my students were considering becoming mathematicians. Some mentioned scientific and engineering fields, yet I can recall only one former student who mentioned specifically becoming a professional mathematician. These young women did not lack confidence in their mathematical abilities, nor did they see mathematics as a field better suited to boys. Simply put, the idea of becoming a mathematician just was not on their list of dream jobs, and I often found myself wondering why.

The second issue that brought me to this study was my own experience as an undergraduate. I declared my mathematics major during my freshman year, and at the time, I had never really considered majoring in anything else. I enjoyed mathematics, and it had always come (and continues to come) easily to me, so it made sense to major in it. Yet, in the first semester of my junior year, I changed my major to economics. Even though I still enjoyed mathematics and was excelling in my coursework, I had begun to question the point of it all. It was fun, but what on earth was I supposed to do with it when I graduated? Economics presented a viable option that involved a great deal of mathematics but also provided what I felt at the time would be more tangible financial benefits. That turned out to be a poor decision for me, and I later came back to mathematics when I pursued a master's degree in mathematics education. But I continued to question why this detour had occurred. It was not due to a lack of confidence on my part or to any perceived gender subjugation. As best I could decipher it, I was motivated largely by the need to be able to support myself financially, and studying economics was the most viable option at the time for achieving that goal. Financial stability is still an important goal for me, but other issues have become important as well, such as a passion for the subject, which I simply did not have with economics.

How did these experiences translate into expectations for the findings from this study? In short, all of my experiences had revolved around confidence, not the lack of it, so my central assumption was that the women in my study would be motivated by positive factors rather than negative ones. Also, I believed that, regardless of their choice of major, the choices that these women made would represent a rational decision process. Specifically, I did not want to assume that a particular choice of major represented a better and more rational decision than others. In sum, an understanding of why these women did or did not choose to study mathematics required an equal acceptance and open discussion of all of the academic choices available to them, as I did not believe that their choices about the viability of mathematics as a field of study were being made without the consideration of the other options available to them. I wanted to gain an understanding of these women's choices in the context not just of their mathematical experiences but in their overall academic experiences, and I felt that this larger contextual understanding was the best way for educators to understand and address the specific issue of the underrepresentation of women in mathematics.

CHAPTER 4

A MODEL OF ACADEMIC CHOICE FOR MATHEMATICALLY TALENTED COLLEGE WOMEN

This chapter is divided into three parts. In the first section, I give an overview of the academic choice model, with a brief description of the domains of the model and how they interact. In the second section, I give excerpts from the discussions on the Web site and from the closing interview and demonstrate how these excerpts provide evidence for the domains. I also discuss the potential points of conflict and resolution for the domains. I also give data specific to the choice on the part of the participants of whether or not to major in mathematics. The data in this section are collective data from all of the participants. In the third section, I tell the individual stories of three participants, detailing the conflict and resolution that they experienced at the different domains. In the second and third sections, all data excerpts collected from the Web site are unaltered in terms of spelling, grammar, and punctuation. Any adjustments I made, including explanatory or omitted text, are indicated by brackets.

A General Description of the Model of Choice

On the first day of online data collection, I posted a question to both groups concerning the participants' beliefs about their mathematical talents. I had the idea that their beliefs about their mathematical talents would have had a large impact on whether they chose to major in mathematics or not major in mathematics. I was quite surprised when, on the same day, Elizabeth posted the following entry:

> I think in the overall scheme of things, talent is not the most important thing. Talent is secondary to passion.

The other members of Elizabeth's group strongly echoed and supported her sentiment. Surprisingly, a similar sentiment arose in the other discussion group, independent of Elizabeth's comment. It was almost as if the participants were saying to me, here's what's really important to us. They continued to explore this idea of passion throughout the entire 12-week online discussion, gradually elaborating on what they meant by *passion*. Passion was not simply enjoyment of a subject (although that was certainly a part of it), but it was more the sense that what they were doing had purpose and value. Any theoretical representation of the factors that influenced the participants' choices of majors would have to focus on this sense of purpose and value that was at the core of their decision processes.

It was soon obvious, however, that value alone was not sufficient to describe why these women had made their choices. Note that Elizabeth claimed that talent was secondary to passion and not that talent was irrelevant. Talent was necessary in order to be successful, but that success was considered less valid if it did not match a participant's sense of values. The online discussion was peppered throughout with other factors that influenced the participants' choices of majors, but each of these factors was discussed in a way that showed how they culminated in a need for value and worth. This sense of relative and culminating importance led to the development of the model of academic choice.

Regardless of major, the women in this study made choices about their major based on four domains: environment, behavior, talent, and value. These domains are listed in order of relative importance, from least important (environment) to most important (value). Although the relative importance of these domains does not necessarily reflect the order in which the participants addressed the issues present in the domains, the culmination of the four domains can be demonstrated by the following sequence of questions:

- How comfortable am I in the environment of my major department?
- What kind of behavior is expected in the department in order to be successful?
- Do I have the necessary talent to be successful in the department?
- Do I believe those talents and behaviors are valuable for me to cultivate?

This model does not assume that the student will necessarily reach a total agreement between the four domains, as new information and experiences will cause the student to constantly reevaluate and reexamine her choices. It is unlikely, therefore, that a student would ever reach a point in her decision process when she experiences no internal conflict whatsoever with the academic choices that she has made, and the data from the participants in this study supported the perspective of academic choice as a dynamic set of experiences rather than a single discrete event. The relative importance, however, of these domains does reflect the likelihood that a conflict would cause a participant to change her major. When a conflict was experienced at any level (e.g., “My major requires doing lots of proofs, but I’m not very good at proofs”), the participant resolved this conflict by either reaching a compromise within the self about her current major or by changing her major outright. A conflict in the environment domain often resulted in a internal compromise which did not cause the participant to leave her department, whereas a conflict in the value domain often resulted in the more dramatic decision to change majors. It was therefore essential to the participants that they experience little if any conflict with the values of their major departments, as a conflict in this domain most likely resulted in their leaving the department. The relative importance, culmination, and potential shift caused by conflicts are demonstrated in Figure 1.

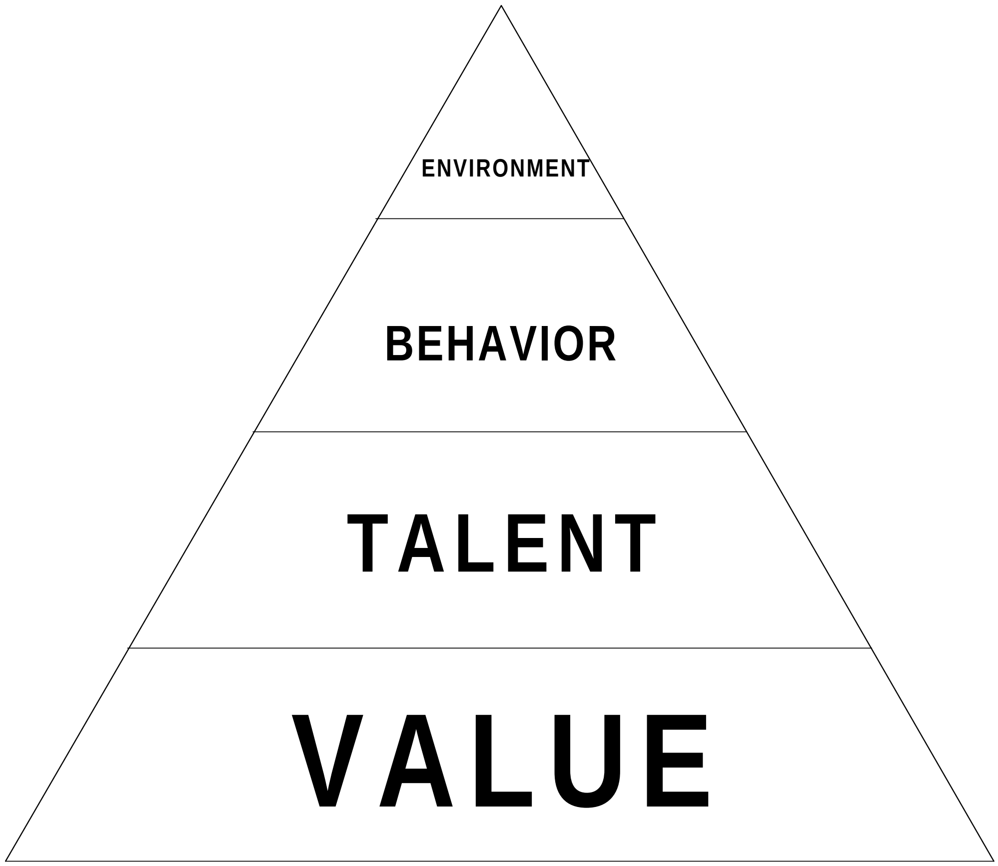

Figure 1. The model of academic choice

The findings for the general model of choice are consistent across participants when applied to the particular decision of whether to major in mathematics or not. The participants cited few if any conflicts with the environment of the mathematics departments at their colleges and universities, and this domain had relatively low importance in their decision of whether or not to major in mathematics. On the other hand, many participants had conflicts with the values of the mathematics departments at their colleges and universities, and those conflicts were often cited as the central reason (and occasionally the only reason) that a participant was not majoring in mathematics. Therefore, the domain of values held a relatively high level of importance in the participants' choices of whether or not to major in mathematics. Also, all participants who were majoring in mathematics claimed that they found their majors satisfying in the value domain, confirming the general finding that satisfaction in the value domain was essential to a participant's overall satisfaction with her choice of major.

Evidence from the Domains

Environment

Discussion of the environment domain addresses the following question: How comfortable am I in the environment of my major department? Discussions about the environment of a department were often made in the context of the larger college experience, but participants also discussed the professors in their particular departments as well as the peer support they received in their chosen fields.

The College Experience

It is not unusual for talented students to experience surprise and some discomfort when they enter a highly competitive college or university. No longer are they the smartest person in the class; rather they are only one of many talented students. This phenomenon was particularly relevant for this group of women, given that they had chosen to attend some of the most prestigious technical schools, universities, and liberal arts colleges in the country. Not surprisingly, some saw their entry into the college environment as a time to reassess their own abilities and talents:

> When I got to college and discovered how talented at math everyone else was in my classes, I got kind of discouraged.—*Katherine (Web site)*

> I'm just now discovering all the other people who were also at the tops of their classes in school. It's a humbling experience.—*Knox (Web site)*

This feeling of discouragement did not last long, however, as they quickly sought out and found new groups of intellectual peers. They also cited a series of good teachers and challenging precollege environments as having provided them with the skills needed to make a smooth transition to their challenging college environments:

> [My high school] was very academically rigorous. I would come home from school or practice, and I would do my homework for 4 or 5 hours a night and then go to bed. It built my study habits, and I have great study habits for college because of that.—*Hadley (interview)*

> I had a series of really good math teachers [in high school] who challenged me in exactly the way I needed to be challenged.—*Rachel (Web site)*

Even though some of the women in this study experienced moments of discouragement and doubt on entering college, most found the added challenge of the college environment to be invigorating and exciting:

> I was exposed to rigorous math, and it was just one of the most beautiful and satisfying things I have ever done.—*Clara (Web site)*

> Coming to college was great! My love of math only got stronger and I could do math in the exact capacity that I wished.—*Lola (Web site)*

This feeling of challenge was particularly exciting for Lola, as her portrait of the academic challenges put forth in her high school was particularly bleak. She and her parents had constantly struggled with the high school administration over placing her in both advanced mathematics and art courses:

> [The administration] couldn't understand how I could be talented in math and how I could paint.—*Lola (Web site)*

Few of the women saw the academic challenges (or lack of challenges) they experienced before college as being so bleak, and none described the additional challenges and academic rigor of their university environments as a source of conflict. Their overall responses to their new challenges were positive.

One challenge in the university environment that was not received so favorably was that of choosing a specific area of study. These women all possessed multiple talents, and many of them found the prospect of choosing a specific field of study to be quite daunting:

> In high school, I was torn between loving English and art some days and math and physics on other days. Now that I am in college, I dislike having to focus so much.—*Jane (Web site)*

> One of my biggest problems is that I enjoy practically everything taught in school!—*Rachel (Web site)*

Many of the women were able to counter these feelings of academic isolation by taking advantage of the variety of academic and extracurricular opportunities available at their universities. Rachel and Emily both chose majors in interdisciplinary fields. Jane, Lola, Hadley, and Katherine all had double majors, and Nan had a minor in Italian studies. Maude chose to major in a field unrelated to her career plan of medicine. Both Nan and Rachel took time to study abroad. Maude, Nan, and Hadley had all chosen a liberal arts college because they thought that this choice would give them more opportunities to take courses outside of their majors. Esther and Elizabeth played sports, and Elizabeth also sang in the choir. These are just a few examples of how these women actively sought out solutions to their concerns about academic specialization within their university environments.

Professors

The women in this study occasionally gave what appear to be contradictory reports of the academic environment provided by their professors. On the one hand, most gave glowing reports of individual professors or sometimes entire departments, whether of mathematics or not:

> I have a lot of respect for the professors in this department, which had some influence on my decision [to become a mathematics major]. They really know you and they push you because they want you to be the best you can be.—*Nan (Web site)*

> My observation has been that the math department, as all of the departments here, [has] to be very appealing to students. [. . .] The professors are always very available, and will to give you help whether it's with a question on a problem set, or deciding on a major. My math professor was always there to answer any questions that we had and he always really wanted to make sure that we all understood. He was definitely approachable.—*Rachel (Web site)*

> I got to know my professors really well, going to office hours, just in class, asking questions, and I think that was a great benefit. [. . .] They were very much friends of mine, I mean beyond the classroom. I know that I can stop by an office and ask questions pretty much anytime.—*Hadley (Web site)*

> Every psychology professor I had was very willing to answer my questions and [was] very personable.—*Katherine (interview)*

> I didn't have any terrible professors, but I had some great ones. My organic chemistry professor was great. He was just really passionate about it, and really devoted to teaching. My genetics professor was the same way. He was a great professor and a really nice person, too.—*Maude (interview)*

These glowing comments cut across subject area and school size, indicating an overall respect for the academic environments provided by their professors, regardless of major.

On the other hand, some of the same participants whose comments were cited above gave a highly critical account of some actions of their professors and departments. For example, just a few days before Nan made her comment about how much "respect" she had for the professors in her mathematics department, she had made the following bulletin board entry:

> I know that at my school, they definitely try to weed people out with the survey math courses. They specifically teach them in a way so that it's different from what you learned in AP Calc. You have to know WHY you are doing things instead of just how to do them. [. . .] I'm not sure if math departments do this because they are snooty elitists who just want to teach the best of the best, or if they just don't want to teach kids the same stuff they've already learned. [. . .] I guess the professors want all the math majors to go to grad school and be just like them.—*Nan (Web site)*

Her allusion to mathematics professors wanting to prepare the next generation of research mathematicians resounded strongly with many participants. Although they found their professors and departments, on the whole, to be supportive and friendly, they were put off by the prospect of becoming professors themselves:

> My father keeps trying to convince me to be a professor, but I hate the idea of doing research. Also, I feel like professors don't always teach…they profess. [. . .] I find that at my university, there are many professors who are brilliant, and everything comes easy to them…they just understand everything. But they just can't teach.—*Katherine (Web site)*

It is worth noting, however, that the critiques provided by these women did not center on the environment of their departments (still described as friendly and supportive) but rather on their perception of the behavior expected in their departments (research and theory). This issue of behavior is discussed below.

It is also worth noting that, when describing their positive environments, the participants did not make distinctions according to the gender of the professors, although they certainly noticed that the large majority of their professors were male (across all departments and not just mathematics). Furthermore, not one participant was able to point to a situation in which she felt unwelcome or unequally viewed by her professors because of her gender. In many ways, these women seemed to view their college environments to be unaffected by gender, at least as far as they were concerned:

> Female professors versus male professors in college—one didn't appeal to me more than the other, but I think that was mainly because I wasn't

> thinking about decisions about my life outside academics. However, I would prefer a female advisor [in med school] because I think that I would be able to talk to her more about family and kids and how to balance things.—*Maude (interview)*

In sum, the participants recognized the need for female role models in their careers but not necessarily in their undergraduate academic classrooms. Given that only one of the women in this study (Clara) was planning a career in a university, it is perhaps not surprising that the limited number of female professors was not cited as creating a conflict within their academic environments. One might well ask whether the paucity of female role models at the collegiate level might have been a reason that these women were not choosing careers in academia, but the discussion below of the findings for the other domains (particularly the value domain) indicates fairly clearly that they had other reasons.

The participants did not view every professor with such high regard as that described at the beginning of this section. Katherine, in particular, described a very negative experience she had had with a professor in her first advanced mathematics class:

> The professor announced before he even started the class that this was his last semester and he didn't like the subject of this class. That automatically put a damper on things. [. . .] He didn't do anything. He stood in front of the class and lectured really quietly. When people asked questions, he wasn't really responsive at all…he just shied away from them. He went [to class], he lectured, and he left, and he wanted nothing else to do with other people in the course. I even went to his office hours, which were sometimes very busy, and he refused to set up other meeting

> times with me. He seemed not to care that I didn't understand. —*Katherine (Web site)*

Despite this bad experience, Katherine did not choose to change her major from mathematics to another field. Rather, she assessed what she felt she needed that she was not getting from this professor and actively sought out other professors in her department who she believed would be more responsive to her questions and concerns:

> I find that I ask a lot of questions in class, and some professors get nervous and uncomfortable with that. So, I think I tried to find professors who weren't necessarily the most interesting and full of life, but the ones who would be responsive to me asking questions. I ended up being successful in finding good professors after this bad one, but that is because I sought them out. The ones I found after him were probably an 8 or 9 [on a scale of 10]. They were good, solid professors.—*Katherine (interview)*

Other participants found equally effective ways of working out their conflicts within their academic environments. Some accomplished that goal through direct negotiation with a professor:

> He actually listened to us and was able to ease back on the pace of the class and still accomplish what he wanted to accomplish with the class.—*Knox (interview)*

Others circumvented the problem altogether:

> I have had one really bad professor, but it was at a point where there was a group of us, and we were all good friends. So we just basically ignored everything she said and studied on our own and did fine.—*Hadley (interview)*

Each of these excerpts illustrates how the participants took responsibility for their own learning environments. Also, they were able to address their conflicts with professors within those environments. None cited the academic environment created by her professors as a reason that she would change or had changed her major.

Peers

Recall that in Katherine's description of her college experience, she found herself initially somewhat "discouraged" by the academic capabilities of her peers. It was not long, however, before Katherine saw these peers as a source of support and strength rather than discouragement:

> I have found people to work with who motivate me…we all struggle together.—*Katherine (Web site)*

The participants continually emphasized the value of effective study groups. These groups gave them the motivation and skills to succeed in their departments, and all actively sought out a group of people who would serve that purpose:

> At first, we worked alone and struggled, but then we figured out how to work together. It was wonderful! We all learned from each other, and gained so much more insight into the proofs.—*Clara (Web site)*

Not only did these study groups serve the purpose of academic support, but the participants also cited their study groups as being a source of some of their best friends:

> My group is the five people that I work with the most. We end up seeing each other a whole lot, and when we don't see each other, we just try to hang out otherwise. Like, during finals, we didn't have much [work] to

> do together, but we hung out a lot anyway. They're really cool people, and we have a lot of fun together.—*Jane (Web site)*

> My seminars sort of introduced me to a lot of my closer friends. In these classes, we got to be pretty tight. We'd spend a whole evening working on a problem set and laughing!—*Rachel (interview)*

Also, being friends was not only a byproduct of a successful study group but was often viewed as essential to the creation of a good study group:

> [One of my groups] was randomly thrown together, and we didn't mesh at all. They would let one person work on it, and they didn't help them at all, and they didn't ever get together really.—*Jane (interview)*

> I would say that one of the projects which was not very successful was a final project we had to do last semester where we designed and built a contraption that allowed us to walk on water. In theory, it was a great project, but my group was horrible. Of the four, two were major slackers, and one was very stubborn. [. . .] Although our final project worked well enough, I know that we could have done a much better job than we did.—*Hadley (Web site)*

None of the participants cited any difficulty in finding a supportive peer group within her department. Many did comment on the small number of other young women in their departments, but they did not cite this as a problem or a source of conflict. Just as they did not recognize any difficulty with or differential treatment from their mostly male professors, they did not sense differential treatment in their relationships with their male and female friends:

> After coming from an all-girls school, it was different to have guys in my classes in general. Having only guys in a couple of my classes was very bizarre, but after less than a semester with those guys, we were all good friends. I don't think it mattered at all.—*Hadley (interview)*

> I felt equally treated as the males. As far as a peer group, it wasn't really important to me to have other girls in my major, because I related well to guys too. So, I didn't have a female peer group, but I don't think I really needed it. As far as I can tell, in my department, there's no favoritism.—*Nan (interview)*

Some participants even stated that they found their minority status to be motivating:

> I always enjoyed being one of the only girls in my math classes.—*Rachel (Web site)*

> I wanted to prove that I could do it (as a female, and especially as the only female in my year.)—*Hadley (Web site)*

This observation is not intended to imply that the participants found their female academic peers less important or engaging than their male peers. It is simply to say that gender parity within a department was not essential to a participant's decision to choose or remain in that department. What did seem essential was the existence of a variety of opinions—both male and female—that a participant could use to inform her decision:

> The friends that I ended up hanging out with throughout school were mainly the people that I hung out with freshman and sophomore years, and those happen to be the people that I met in my science classes. My closest friends were all science majors, and within that group, for whatever reason, there were a lot of women. By my junior and senior years, it became that the girls were really important. I realized how much I valued spending time with other women, and the fact that these were such amazing women! This is a really ambitious, talented group of women, but at the same time they are a lot of fun. I think that I lucked out in finding them. But I still enjoy hanging out with both men and women, because I think that too much of [one point of view] is boring. Besides, even among women, we will not all have the same point of view. Even among my group of friends, there are a couple that don't

> want kids or to get married. It's not true that because we are women that we will all have the same experience.—*Maude (interview)*

In sum, none of the participants cited the lack of a gender peer group within her academic environment as a factor that influenced her choice of major.

Conflict and Resolution in the Mathematical Environment

As the data demonstrate, the participants found few conflicts with the environments of their major departments. The conflicts that were cited were usually resolved within the self while staying in a department rather than by leaving it. The fact that these women felt little conflict with the environments of their current majors, however, did not necessarily mean that they found the environment of their university mathematics departments to be hospitable or inhospitable. Had those who had chosen to major in fields other than mathematics done so because of conflicts they had in the mathematics department at their universities?

For the overwhelming majority, the answer was no. Only Emily cited the environment of her university's mathematics department as being a reason that she chose not to major in mathematics:

> One of the reasons I did not like math classes was that it was so obvious who was good and who was bad…it seems cold and harsh.—*Emily (Web site)*

She resolved this conflict by choosing a major (history) that she felt "had more possible answers than just one," where everything was not so "fixed." However, the other participants who were not majoring in mathematics were just as likely as the mathematics majors to describe the positive aspects of their mathematics classes, and the positive comments about her mathematics department given by Rachel (who was majoring in history and science) were an interesting contrast to the negative comments made by Katherine (a mathematics major). Although an absence of conflict in the environmental domain was clearly important to these women, the conflicts they experienced in their mathematical environments were not so serious as to cause them to resolve their conflicts by moving from mathematics to another field. Also, the positive aspects of a mathematical environment were not compelling enough on their own to attract these women into the field. In sum, lack of environmental conflict is important, but other domains played an equal or more compelling role.

Behavior

Discussion of the behavior domain addresses the following question: What kind of behavior is expected in the department in order to be successful? This question addresses not just classroom behavior and expectations, but behavior and expectations outside the classroom as well. The issues discussed in this domain were collaboration on work, expected and desired level of effort, measures of success, and the relationship between success and knowledge.

Collaboration

In the previous discussion of the environment domain, working in study groups and with peers was cited as one of the more positive aspects of the college experience. Whereas the participants' precollege experience had been marked almost entirely by independent work, all of them took advantage of opportunities in their undergraduate programs to work collaboratively with peers. For some, these groups were a required part of their programs, through labs and collective projects:

> Right now, in my bioengineering class, we're working on a project which culminates in a basic design of a heart-lung bypass machine. My group has been working on the preceding parts of this assignment for almost two months…we got it the Monday after spring break, and we've been working hard ever since!—*Knox (Web site)*

Others were encouraged, but not required, to work collaboratively:

> We were allowed to work on homework in groups if we wanted to, so in all my free time, it's like, meet at 6:00 and start on this assignment and meet at 8:00 and start on that assignment.—*Jane (interview)*

Others sought out collaboration on their own, without any specific suggestions from faculty in their departments:

> I was more successful in my classes when I chose to work with another person. We set each other off. We [both] seem to . . . understand the material, but somehow we would, in talking the problem out with each other, figure out how best to approach the problem.—*Katherine (interview)*

Many of these women also recognized that not all collaboration is good collaboration and subsequently sought out groups that would help them meet their learning goals:

> The other group would every week assign a different person to write the lab report, whereas every week, we all worked together until the lab report was done. I feel like we probably learned a lot more actually, because we all figured out the data.—*Jane (Web site)*

> I took another class on logic and the philosophy of logic, and that study group totally became my crutch. I was not as successful in the class as I could have been if I had worked a lot [on my own] outside the study group.—*Rachel (interview)*

Rachel's sentiment about needing to work more on her own in addition to working with her group brought up an interesting dilemma: At what point should one suspend collaborative work in order to work (and be assessed) independently? For some, the question was whether to suspend collaboration at all, given that they viewed the work of their professors as often involving professional collaboration. This apparent contradiction between assessment at the undergraduate level and assessment at the professional level was a cause of concern for some participants:

> If you are trying to prove something you are not as familiar with or that you aren't certain is true, you can come up with proofs that appear to be correct but in actuality have flaws. That is why when professors come up with some brilliant new theory and "prove it" they get to ask their colleagues to check it over.—*Katherine (Web site)*

> [Professors] at least get to have someone check their assumptions before being graded (i.e. criticized).—*Knox (Web site)*

The participants' conflicts were resolved by the sense of satisfaction they experienced after successfully completing a challenging assignment on their own:

> I like sitting down and working on an exam for hours and hours and having something click and figuring out the problem. [. . .] When I

> understand what I'm going and do well on an exam because of it, the feeling of accomplishment is immeasurable.—*Nan (Web site)*

Therefore, although the participants did sense some mixed messages between what they as students were expected to do versus what academic professionals were expected to do, those mixed messages caused them little difficulty, given that they were already very accustomed to working independently in their precollege academic classes.

Expected Challenge

Another issue in the behavior domain is the question of how much time and effort are expected by a department in order for a student to be successful. Rather than shying away from departments with a heavy workload, the women in this study acknowledged both their need and desire for hard work in order to develop their talents fully:

> Being good at something doesn't just require natural insight. It requires long hours of work and concentration.—*Esther (Web site)*

> [When choosing a class], it's not so much which one is going to be harder, but where am I going to learn the most, which is usually the harder one. It's just a challenge to your mind. …I just like to push myself. It's like exercising. …You like to see where your limits are sometimes.—*Elizabeth (interview)*

> I would opt for a challenging class because I would rather not be bored.—*Katherine (interview)*

Regardless of their major, these women saw academic challenge and rigor as an essential and attractive part of their major areas of study. A challenging academic curriculum was so essential to some that they felt it necessary to make their studies more challenging through their own efforts:

> [On a scale of 1 to 10 for difficulty,] I'd rate my math major as a 10, because I take it very seriously. For others at my school who don't take math as seriously, a math major might only be rated a 5 for difficulty.—*Clara (Web site)*

> If there was a project, I would try to put more into it. It was a chance for me to do something different.—*Hadley (interview)*

Although the participants universally viewed academic rigor as a positive aspect of their academic choices, it did cause some conflict with the issue of academic specialization referred to in the environment domain:

> Sometimes I wish I had chosen a less rigorous major so I could take more classes that I enjoy in other disciplines.—*Knox (Web site)*

This conflict was not enough, however, to cause Knox to leave her academically rigorous field of bioengineering.

It is interesting to note that those participants majoring in mathematics perceived the difficulty of their mathematics majors as an attraction and not a detraction:

> The difficulty of my major definitely influenced my choice. I was choosing between psychology, economics, and mathematics, and I chose mathematics because I knew I would be challenged a lot and I thrive on that. [. . .] If I was ever told that I would be spending over twenty-five hours on a math test in high school, I would have flipped! Now I know that it's just what I have to do. That's just how much work I have to put into be successful, and I like that.—*Nan (Web site)*

This statement is in direct contrast to research that claims that talented women are drawn to easier activities that ensure success and away from activities, such as mathematics, that have a high level of perceived difficulty (Dweck, 1986). It was not true, however, that all the participants found mathematics to be a difficult and challenging major:

> I would consider my math major to be about a 3 [on a scale of 1 to 10 for difficulty]. All you had to do was study and do homework. Chemistry I would consider about an 8. I'm in lab about 12 hours a week (at least) and I turn in about 30 pages of lab reports every week, plus lecture classes and research. But I love it, as stressed as I sometimes get…I'm where I want to be.—*Elizabeth (Web site)*

Elizabeth's viewpoint, however, only serves to reinforce the notion that these women were drawn to academic activities that they perceive as challenging and rigorous. Elizabeth comment also points to the idea that the participants' notions of challenge were not externally defined, but were based on their personal perceptions. In a sense, these women were searching for academic challenges that were personally optimal—not so easy that they were bored, but not so difficult that they were unable to feel a sense of success and accomplishment.

Success and the Nature of Knowledge

To analyze the kind of behavior that leads to success in a department, it is important to note what these women viewed as academic success. Although all of them had made exceptional grades in all of their college and precollege courses, they were uncomfortable with defining their successes through their grades:

> In middle school, success was defined in terms of a simple grade. But I think success means something different now. [. . .] I think what is most important is that the class changes your thinking. I would like to be changed by a class.—*Esther (Web site)*

> For me, the question about being "successful" in an academic setting is not so much a question of the grade I got, but of whether I got what I wanted out of the class. I just believe there is a big difference between being successful and getting good grades (i.e. when your teacher thinks that you're being successful.)—*Rachel (Web site)*

Such statements do not imply that these women did not enjoy getting good grades. They placed great value in their high grade point averages, but only when they felt that their grades reflected what they had actually learned:

> I'll write a paper in forty-five minutes, and I'll get it back and it's an A-, and I really feel like it's a cheap grade, like it's not worth anything. But if I have a take-home exam and I'm working on it for sixty hours or something, and then I get it back and it's an A, then I feel a lot better and more proud about that.—*Nan (interview)*

> I don't like doing things just for the grades. OK, I admit, a little narcissism is involved in wanting good grades…there are always ulterior motives…that 4.0…ooh! But seriously, if I make a B, it means I don't know the stuff as well as I want to know the stuff. When I get out of physical chemistry, I want to say that I know physical chemistry. I want to know it well. So I want that A.—*Elizabeth (interview)*

They also recognized the practical importance of grades when it comes to graduate and professional schools and job searches, but they defined their successes in terms of the knowledge that they acquired while working toward the grade. This view is consistent with the notion of personally optimal challenge, where an easy "A" would not be valuable or desirable.

The next question is the following: What do these women see as knowledge? Or, what do they think their departments and professors see as knowledge? If they had to determine within their departments what behaviors would lead to success, and they defined success in terms of knowledge gained, then it follows that they had some sense of what counted as knowledge in their academic environments. For some, valuable knowledge came from the ability to apply theory to the physical world. Knowledge was viewed as a tangible product, either through a physical entity or human relationships:

> Success is whether you got a final product, and how much work you put into the product, and how much you got the group to work together on the product. [. . .] My group had our project published in a school journal, which was very cool.—*Hadley (Web site)*

> Everything that I studied in psychology seemed to be related to things that I had seen. It is common sense. I felt like I was able to apply my knowledge.—*Katherine (interview)*

> There is something really beautiful about how math seems to fit the outside universe.—*Esther (interview)*

In fact, the inability to "see" the product of their knowledge was cited by those participants who held this view of knowledge as one of the major conflicts that they experienced with their more theoretical studies:

> I don't think any of the theoretical stuff interests me—it just doesn't give me the thrill that mechanics [does].—*Jane (Web site)*

An alternative view of knowledge (and the products of knowledge) centers on the ability to abstract from the tangible and practical and ultimately to theorize. In this case, the valuable aspect of knowledge is the process (theorizing) rather than the final product (a theory):

> Things that look simple at first glimpse are shown to be beautifully complex on inspection…and vice versa. But then that complex thing becomes simple again when you see something you had not before…then you see something else…and on and on. It all comes down to awe. I'm in awe of this system that has NOTHING to do with creating or designing…this system that controls my every breath and thought. I think that we don't have the capability to understand the inner workings of the world around us…but darnit…I'm going to try.—*Elizabeth (Web site)*

In both views of knowledge, knowledge is created by the knower, but exactly what the individual believes has been created (a product or a process) can vary widely.

This was the point at which many of the participants experienced a conflict with the expected behaviors of their mathematics departments. All of the participants believed that the central expected behavior in their undergraduate mathematics departments was doing proofs. You must do proofs in order to be successful, and therefore proofs represent what counts as knowledge in a mathematics department. For those who held the view of knowledge as product, this expectation was frustrating:

> For me, [a proof] is something that has to be written out step by step (including the steps which at times seem so logical that I don't understand why they have to be included) and in the "correct" fashion. [. . .] I don't enjoy the proofs because I don't like having to prove what someone else has proved years ago in their exact way.—*Hadley (Web site)*

> In math classes where they have you do proofs, you are proving stuff that has been known for years. I have a problem doing it because it seems so

> logical and makes sense to me, but to try and actually prove it seems kind of dumb.—*Nan (Web site)*

These participants saw the knowledge product as unoriginal, and the rules for creating the knowledge product seemed ambiguous. Not only was the final product (the proof) not tangible, but the proof had been done before and therefore no new knowledge had been created. Participants who held this point of view believed that they were engaged in a form of repetition, but repetition in which the steps were not clearly defined. It is worth noting, however, that these women were not questioning their abilities in doing proofs but rather the purpose and usefulness of such behavior.

For those participants who held the view of knowledge as process, proofs held an opposite position on the spectrum of purposeful knowledge. Proofs represented the essential nature of abstraction and theorizing, and they also provided an opportunity for intellectual creativity:

> Some people complain about having to include statements that seem “obvious” in their proofs or having to write statements in sequential order, but they forget that the elegance of a proof matters just as much as the content. Just as a good poem is one that not only communicates a deep idea but is also skillfully written, a good proof is one that communicates a deep idea clearly.—*Clara (Web site)*

> I think it is very challenging philosophically to look at a very basic algebra proof, such as: A^(M*N) = (A^M)^N…well, of course…but prove it…man…that can be very beautiful, when you start working with how the math behind the math all fits together. It’s a very discrete way of looking at the way you naturally see the world (by your educational conditioning) and challenging it. Asking why. Personally, I think the best way to understand something is to prove something about it. I

> equate this to a quote from Slingblade…"You have to see something explode to really understand it…to see all those little parts on fire…" A proof is like that…you rip apart the system involved.—*Elizabeth (Web site)*

Some participants, however, did acknowledge that mathematics represented a wide spectrum of intellectual activities and not just proofs, and that one could choose an academic field in which the requisite mathematical knowledge was more suited to the individual's approach to knowledge:

> Math can be broken into two parts: the computational and the abstract. It is like the difference between being a pure scientist and being an engineer…there are two completely different thought processes involved…the organizational (for computational, applied math) and the analytical (for abstract, theoretical math).—*Elizabeth (Web site)*

> College math is different from any other math you do before that. In our school, the students who don't like this [way of doing math] usually become engineers or something like that where the math is more applied than theoretical.—*Nan (Web site)*

The participants also took great pains to avoid placing one kind of mathematical knowledge and behavior on a higher plane than another. Rather they discussed the different options in terms of individual preferences and talents.

Conflict and Resolution Concerning Mathematical Behavior

The conflicts (or lack thereof) in the participants' perceptions of mathematical behavior were surprising. The conflicts appeared not in expected areas (task difficulty) but in unexpected areas (the nature of knowledge). No participant cited the perceived difficulty of a mathematics major as being the reason she had chosen not to major in mathematics. In fact, Nan specifically cited the perceived difficulty of a mathematics major as being a central reason she had chosen to major in mathematics. The participants placed little emphasis, however, on how difficult others perceived a mathematics major to be. Some expressed contentment with the respect that they received from their peers:

> All my friends who are humanities majors joke that I must be taking math five-million or something.—*Katherine (Web site)*

However, none claimed to have considered her peers' responses when deciding to major in mathematics. Rather, the participants who did choose to major in mathematics claimed that their choices were based on an inherent enjoyment of the subject and a desire for challenge.

There were many more conflicts for the participants when mathematical behaviors were considered as an aspect of the nature of mathematical knowledge. Hadley cited the conflict over whether proofs constituted new knowledge as a central reason for her changing her major from mathematics to engineering:

> The largest problem I have is that proofs seem very obvious to me in that I never put enough information to make it an "official" proof. For this reason, I am not a math major; I major in an applied math field.—*Hadley (Web site)*

As quoted above, Nan also expressed some concern about the role of proofs in the creation of new knowledge, and in a later Web site entry, she stated that she would have changed her major from mathematics to applied mathematics, given the opportunity:

> They just added an applied math major for next year, which I would have done had it been available to me, but I was forced to do the theoretical stuff. [. . .] I definitely struggled more in the classes where it was all proofs. It was all abstract things. My senior seminar was in topology, and it was visualizing things in the 4th dimension. That's totally beyond me.—*Nan (Web site)*

Nan, however, did not change her major. In fact, despite her conflicts with the knowledge products obtained through proofs, she was able to find enjoyment in the proof process:

> I think the shift for me was when math became more creativity and less regurgitation. When there were actually problems you had to think about as opposed to just memorizing formulas. [. . .] I didn't find this in Calculus I or II, but [I did] in the higher level, theoretical classes.—*Nan (Web site)*

The other mathematics majors in the study (notably Clara) also expressed great satisfaction with the creative aspect of proofs. It was not the case, however, that those participants who chose to major in fields other than mathematics did so because of conflicts with the abstract nature of knowledge inherent in proofs. An illustrative case is that of Elizabeth, who despite her impassioned statements about the essential importance of proofs and theorizing changed her major from mathematics to the applied field of biochemistry. Therefore, although some conflicts did arise in the domain of mathematical behavior, only one participant (Hadley) cited those conflicts as the reason that she had chosen to major in an area other than mathematics.

Talent

Discussion of the behavior domain addresses the following question: Do I have the necessary talent to be successful in the department? Much of the answer to this question depends on what the participants believed *talent* meant. The participants addressed their views of talent in general, the implications of those views of talent on their culpability and control over successes and failures, their views of mathematical talent, talents in other areas, and the alignment of their views of mathematical talent with the expected behaviors of their undergraduate mathematics departments.

Views of Talent

Two major issues arose in the participants' discussion of talent. First, they expressed the view that talent is not a pure, unconnected, unadulterated entity. Talent was continually developed through a combination of ability and serious effort. Although the participants' use of the term *ability* did hold some connotations that it was innate, the importance they placed on ability in their definitions of talent was minimal, as they often referred to ability in terms of basic competence, not inherent excellence, at an activity. They placed a much greater emphasis on effort in their definitions of talent. Their definitions were consistent with their desire to seek out difficult and challenging activities. If talent developed through effort, then in their desire to have productive, successful academic careers, they not surprisingly sought out activities that required effort. A characterization of their views of talent as a combination of ability and effort is still incomplete, however, because it does not take into account their desire and willingness to put forth the required effort. The glue that held the elements of ability and effort together for them was enjoyment of the activity:

> Even if you are good at something, you are not going to do it if you don't enjoy it.—*Hadley (interview)*

> If you enjoy something, then you're more willing to work at it. Like if I was taking piano lessons, and I hated it. I wouldn't be talented because I wouldn't want to develop those skills and I wouldn't grow in that area. I definitely think that if you like something, you're more willing to work at it, and then you can become talented in it.—*Nan (interview)*

Much of the question of what major to choose in college was couched in this view of talent. The participants sought out fields in which they had both the ability and the interest necessary to put forth the effort required to meet their personally optimal level of challenge:

> Choosing my major wasn't too hard because it was definitely the only thing that I'm good at AND interested in.—*Nan (Web site)*

The second key issue in the participants' view of talent was that it required much more than simply memorizing and regurgitating facts. Talent in any area required an integrated understanding of the underlying principles of the discipline and the ability to use those principles in innovative and creative ways:

> I think to have real talent in an academic area, you need to have that higher understanding. [. . .] I mean, it is kind of useless to say that you have memorized such-and such theory, because a million people have probably already argued that down. You have to be able to take those concepts and then extrapolate from them. [You have to be able to]

> develop a new idea with it and understand the more abstract concept.—*Maude (interview)*

> For any talent, I think you have to be innovative and not just repeat what someone's told you. You have to be able to come up with things yourself.—*Jane (interview)*

Part of the difficulty the participants had with this view, however, was that talent is difficult to identify and measure through testing:

> I guess [tests] do a decent job of [measuring talent], but there's that someone who may be very talented but do something completely wacky that doesn't fit. [. . .] So, I can't think of a way that people could actually test for talent without lots of one-on-one observation.—*Jane (interview)*

In the environment in which these women were competing for scholarships, jobs, and graduate school admissions, it became necessary for them to acknowledge the role and importance of standardized tests even if they felt that those tests did not accurately reflect their views of talent.

Attributions for Success and Failure

The participants' attributions for success and failure were strongly consistent with their views of talent as a combination of ability, effort, and interest. Given their internalized, self-actualizing views of talent, it was no surprise that their attributions for success were also highly internalized and controllable. More often than not, these attributions were expressed in terms of effort or interest:

> When I do something well, it is because I enjoy it and I take the time to do it well.—*Elizabeth (Web site)*

> I think I tend to give hard work as a reason for success because that's when I feel the most successful.—*Nan (Web site)*

> I think it is a strong determination to do well and good preparation that lead me to success. Generally, those are the two key factors for me.—*Emily (interview)*

Conversely, most of their attributions for lack of success were attributed to lack of effort:

> Most of my academic failures come from procrastination and lack of effort.—*Jane (Web site)*

> The fact that I don't put as much time into my classes is the reason why I don't get the grades.—*Rachel (Web site)*

Even though Rachel referred to grades in her comment, the participants were just as uncomfortable defining their failures in terms as grades as they were defining their successes in terms of grades. Rachel was not referring specifically to getting an "F" or even a "C", but rather the fact that she felt she had not done everything that she could in the course. Therefore, the participants defined failure in terms of disappointment in their lack of personal dedication.

> I tend to give slacking as a reason for failure because that's when I feel like I have failed myself.—*Nan (Web site)*

Given this definition of *failure*, a paper or project that received a good grade but still didn't live up to personal expectations could still be considered unsuccessful. (See Hadley's comment on page 73 for an example of this perception of failure.)

On very rare occasions, some participants attributed failure not to lack of effort, but to lack of ability:

> Failures for me tend to due to a lack of ability—or at least a lack of perseverance, which leads to a lack of the development of ability needed for success in this particular area.—*Katherine (Web site)*

These attributions were confounded, however, by the fact that they viewed ability, effort, and enjoyment as inextricably linked. Therefore, the occasional attribution to ability still demonstrated a strong sense of control over outcomes, just as the attribution to effort did. Also, the tendency to make attributions to effort does not imply that the participants saw ability as playing no role in their successes or failures. Rather, they never saw ability alone as sufficient reason for their successes or failures. Similarly, despite the prevalence of effort attributions, they did not view effort alone as sufficient:

> It's really hard to reconcile when I do poorly and I try hard…that's hard to swallow. I feel like Americans are told that hard work can get you anything, but it hurts when you see that it's not always true if you don't have the ability.—*Jane (Web site)*

Just as all of the elements of ability, effort, and enjoyment were essential to their views of talent and talent development, these same elements were also part of their need to attribute their successes and failures to internal, controllable factors.

On occasion the participants did make attributions to a highly external and uncontrollable factor—luck:

> There are special cases where I succeed no matter what by mere luck, but I don't count on this.—*Emily (Web site)*

These women offered an interesting spin on why an individual might attribute well-earned success to luck:

> About people thinking it's luck when they do well…this is going to sound awful, but I think that's just what a lot of people say. I don't think they believe it deep down. I think that what it comes down to is that people are supposed to be modest.—*Jane (Web site)*

> I know that when I think I was really successful and I say it was luck, I'm usually just looking for someone to say, "No way, good job, you're the best, etc."—*Nan (Web site)*

In other words, although attributing success to ability may be an accurate reflection of how these women actually felt about their work, it did not always appear socially and culturally acceptable to make that attribution, because it comes across as too proud and self-aggrandizing:

> I have one friend who talks about what he does very matter-of-factly. I have never heard him talk about himself just for the sake of it, but he isn't at all shy about what he does or what he thinks about it, and a lot of people conclude from this that he must think a lot of himself. [. . .] I have another friend who is very modest about his intelligence and what he does with it. [. . .] All of this is rather simplified, but my first friend really sticks out in my mind as an illustration of what it is like to be objective about your success when you talk to other people. People don't like you.—*Esther (Web site)*

This notion of socially and culturally acceptable attributions may suggest an alternative explanation for the propensity of effort attributions among the participants. As Jane pointed out, the American culture values hard work and effort as an essential part of talent development, and that value may have affected whether they were comfortable placing their attributions under the heading of *ability*—a term that carries many connotations in the research literature on attribution theory, where it is described as an internal, uncontrollable factor in the standard attribution scheme (Weiner, 1979). This observation does not change the fact that these women appeared to view talent (and their subsequent attributions) as internal and controllable, but it may explain why they were uncomfortable using the term *ability* in their attribution schemes.

The notion of socially and culturally acceptable attributions may also help explain an interesting finding regarding group success. Asked to describe a successful academic situation and the reasons that they felt that situation was successful, a large majority of the women gave examples that were related to success in a group. This gave rise to a long debate as to whether group success was more valuable than individual success:

> I know that some studies have found that women don't take credit for what they have done alone but what they have done in a group. THEIR work isn't as important as the work of the group. [. . .] But with a group, you can really talk about how well you did, because usually (I have found) that the group ends up doing better that I had thought we could do.—*Hadley (Web site)*

> I think that group successes are more fun because you get to share the excitement of figuring something out with others. [. . .] When I do something well by myself, it's not as gratifying because there is no one to share it with.—*Katherine (Web site)*

Given the emphasis on cooperative learning and working with peers in their academic environment, the participants saw their academic cultures as emphasizing success attributions to the group rather than the individual. They may also have observed that individual success was usually measured in terms of a grade rather than a product or learning process, and as already noted, they were uncomfortable with using grades as the sole measure of their successes. Conversely, however, were group failures attributed to the group rather than themselves? Not necessarily:

> In group situations, I tend to see success as a group success, but failure always becomes personal, even when I know deep down it wasn't my fault. I always think I could have done a better job motivating the group or just worked harder and then the group would have been more successful.—*Knox (Web site)*

> It's hard not to take on the responsibility of the group's failure when you are a part of the group.—*Katherine (Web site)*

Although these opinions do not necessarily represent the views of all the participants, they were another indication of the pressure to make socially acceptable attributions for success and failure. If a participant had said, "I did my part," or "I did well, but everyone else was a real slacker," it might have come across as selfish or as being uncommitted to the valued principles of cooperative group work.

Views of Mathematical Talent

The participants' views of mathematical talent were generally consistent with their definitions of talent (involving ability, effort, enjoyment, and an integrated understanding of underlying principles), but that was not always the case. In the early grades, when many of the participants first began to think of themselves as being mathematically talented, mathematical talent was for them heavily associated with speed and computational accuracy:

> I started to think of myself as mathematically talented in early grade school (1st or 2nd grade). We had to do in-class math assignments, and I always finished them very quickly and did well on them. I would race with two of the boys in the class and I usually beat them.—*Maude (Web site)*

> When I was in kindergarten and in elementary school, I could calculate fast, and that was all that mattered. Math wasn’t complicated when I was young, and if I could calculate fast, I was “good” at it.—*Emily (Web site)*

It is worth noting, however, that not every participant excelled in speed and computational accuracy in her early schooling:

> In elementary school, I was always the last person to pass the arithmetic tests…I mean…I was horrible at them! I think I even had to stay in from recess one time because of it.—*Elizabeth (Web site)*

> In 4th grade, I moved to a new school, and it had this awful linear system for teaching math. I spent two months failing long multiplication pretests over and over just so I could take and fail another test and find out I still couldn’t move onto the next book. [. . .] Once a girl told me that I must be stupid because I was still in the long multiplication book.—*Esther (Web site)*

Another component of the participants’ early perceptions of their mathematical talent arose from their individual performances on standardized measures of mathematical ability and achievement:

> I don’t think I ever thought about being mathematically talented until I did better on the math part than the verbal part of the SATs.—*Nan (Web site)*

> I was given some intelligence test when I was in about 3rd grade, and I did really well on the quantitative and visual sections. Then I took the SATs in the 7th grade as part of some Johns Hopkins program. I rocked the math part, so I guess that is what made me finally realize I was good at math. [. . .] I guess I really never thought about being talented in math until it was brought to my attention via tests. I always liked it, but I was little, and I liked something, which meant just that—I liked it. I never really thought about being good at it until parents and teachers stepped in and made a big deal about it. [. . .] I wouldn't say that my talent is defined by these tests, but it was brought to my attention because of them.—*Katherine (Web site)*

Katherine's comment brings up an interesting point about tests and talent: Tests may not entirely define talent but they may help identify it. Also, in light of the participants' general definitions of talent, they were concerned that certain aspects of mathematical talent (namely, creativity and innovative thinking) would not be measured in these tests:

> I didn't see exams as a quantifiable measure of my mathematical talent. Most of these exams test arithmetic, and I find that I am more interested in (and consequently better at) proving mathematical principles. Thus, even though I did well on the aforementioned tests, I never saw them as demonstrating my mathematical ability.—*Clara (Web site)*

> I was just talking to my [high school] math teacher, and he was talking about this one kid who had thought of this big geometry theorem, and he was talking about how none of [the boy's] teachers would wait [for] him. He thinks really well, but he also thinks really slowly. So, he doesn't do as well as [some other students] on standardized tests. But he really thinks well if you give him a chance to think, and I think that kind of intelligence is just as [important as], if not more important than, being able to take the sine of 75 degrees in your head.—*Rachel (interview)*

Clara spoke about the limitations of standardized tests for revealing and assessing mathematical talent, yet she still did well on such tests. Rachel's description, however, of the student who proposed the geometry theorem points to a particularly interesting dilemma when it comes to standardized measures of mathematical talent. Although most students who exhibit the more general aspects of mathematical talent (ability, effort, enjoyment, and creativity or innovation) will do well on a standardized test of intelligence or achievement, the risk is that the talents of many innovative mathematical thinkers will not be detected by these tests.

Their exposure to advanced mathematical study had provided one of the first opportunities for the participants to view mathematical talent as something other than speed and computational skill. They began to explore the issues of ability, effort, and enjoyment:

> I think I enjoy math because it comes easily to me. So, its easy for me to sit down and do math because I enjoy it on the one side. But on the other side, I enjoy it because it's easy enough for me to understand what my class is doing.—*Esther (Web site)*

> I'm not certain whether I am talented in math or I am just trudging my way through it because I enjoy it. In other words, I'm not sure if I liked it, so I became good at it, or I was good at it so I liked it.—*Katherine (Web site)*

As their beliefs about mathematical talent changed, however, so did their perceptions of themselves as being mathematically talented:

> I think my perception started to change when I took Calculus II in college. I had passed out of Calc I because of my AP score, so I started again in the second semester, and I just couldn't get into it. I did alright in the class, but not really well, and I have yet to figure out why exactly I had so much difficulty with the class! But it really turned me off to math (since I can't say that I had real burning passion for it before that, although I had always liked it), and made me doubt my ability to do it.—*Maude (Web site)*

> When I came to college, [mathematics] was more proof oriented, and I really started to doubt my mathematical ability. I do feel that I have this kind of innate ability to figure mathematical things out that a lot of my friends wouldn't necessarily have, but I think I just encountered more struggles in college with math than I used to.—*Katherine (interview)*

Katherine's comment echoed a popular sentiment among the participants: Although talent involves effort, there is a difference between effort as diligence and effort as struggle. This sentiment also allowed for the idea that mathematical talent is not a fixed entity but can change throughout one's academic career. Specifically, whereas all of the participants saw themselves as mathematically talented at some point in their lives (and had evidence to support that idea), they did not necessarily continue to see themselves as mathematically talented during college.

Another debate on the issue of mathematical talent was whether it required skill at proofs, or whether those who applied mathematical concepts to other areas were mathematically talented as well:

> Coming to college was a real eye opener for me in terms of my math skills in that I found that although I was capable of doing math, I did not have as deep of a grasp as I thought I did. The level of math application

> that I was coming across was doable, but the theoretical/proof work was beyond what I could understand.—*Hadley (Web site)*

Although many participants proposed and accepted definitions of mathematical talent that encompassed both theoretical and applied mathematics, they all strongly emphasized the importance of an abstract, theoretical understanding of mathematical principles:

> As for the person who can add lots of numbers…talented, yeah…but I would never let that put him on the genius level…where I would consider that with someone who truly understands the language.—*Elizabeth (Web site)*

Such observations are not surprising given the strong focus on theoretical skills the participants saw as required in their undergraduate mathematics departments. For those who had chosen a field in which they were applying mathematical principles, there was the question of whether being able to apply mathematical principles would by itself qualify one as being mathematically talented:

> I think if you can't do the more abstract [mathematics], then you are talented in whatever field you are using the math for.—*Maude (interview)*

In other words, although a person who applies mathematical principles to another field may have been using mathematics in a skillful way, that person may lack one of the central elements of talent in a field: an integrated understanding of the underlying principles of the discipline. Therefore, someone who used mathematics to gain an integrated understanding of the principles of engineering would have been developing her engineering talent, not her mathematical talent.

The idea that one could be talented in mathematics or talented in a field that uses mathematics was not in itself a problematic notion for these women. It became problematized, however, if a participant believed that one type of talent required more intelligence than another:

> I think the theoretical part of math takes more "talent" to do well in.—*Katherine (Web site)*

This belief was connected to the belief that mathematical talent gives one a privileged intellectual position. However, the notion that theoretical mathematics requires more intelligence than applied mathematics does was questioned by many participants, who felt that they simply had not been given the opportunity to explore their theoretical talents earlier in their academic careers:

> Mathematical theory is about PROVING properties of mathematical objects in terms of axioms while arithmetic is about APPLYING the properties of mathematical objects. Consequently, one can be talented in theoretical math, but not in arithmetic, and vice versa. I feel that both are equally important, and that one does not require more talent than the other. However, I feel that, too often, one area of math gets stressed more than the other in school. In high school, the application of mathematical principles is emphasized much more than the theoretical area whereas for undergraduate math majors, the theoretical side is emphasized far more than the applied area. Unequal emphasis is harmful because it gives students a one-dimensional view of mathematics.—*Clara (Web site)*

In other words, claims for the elite position of mathematical talent had to do less with the discipline itself than with the way that it was traditionally taught. Absence of mathematical talent was connected to lack of exposure rather than lack of ability. Also, it was not surprising that the participants' views about the relative importance of theoretical versus applied mathematical talent were connected to their views about knowledge as process or product:

> As someone who goes the applied route, I tend to assume a [mathematically] talented person can do applied [mathematics].—*Hadley (Web site)*

Hadley's comment represented the need for her to have internally consistent beliefs about her academic behavior and her academic talent.

Talent in Other Areas

During the interview, Jane expressed some concern over the privileged social and academic position that mathematical talent tends to hold over talents in other fields:

> [My sister] is also mathematically talented, but she switched from architecture to English in college, and my dad was really upset. He said that she was wasting her talent. A lot of us may be talented in other things, and no one ever pays attention. It seems like people don't value that talent as much.—*Jane (interview)*

Jane's assertion may be true for society at large, but the participants in this study appeared to place a great deal of value on their other talents. Although self-perception of mathematical talent had been a principal criterion for participation, most participants freely discussed their talents in multiple academic and nonacademic areas. Some had developed these talents through double majors or minors (Lola, Jane, and Nan), and others intentionally chose majors that would allow them to practice a variety of talents:

> My choice of major was directed at allowing me to work all the sides of my brain, not just the sciency parts! It's also a subject that allowed me to study about a lot of different subjects, but all united by logic and analytical method.—*Maude (Web site)*

> I love history, I love math, I've always enjoyed the science classes that I've taken, my favorite class in high school was my senior English class, and what's there not to like about art or music or any of a variety of other things? The reason that I'm choosing to major in History and Science is because I'm really indecisive. Also, I love to be able to make big connections, either within a field or between.—*Rachel (Web site)*

Some participants had even chosen majors that they felt did not make use of their greatest talent:

> I do see myself as talented in Chemistry…I'm good at it…it makes sense to me. And it's not just that I can do the problems, it's that I understand what's going on. But, I think I was a lot more "talented" at math (came easier, understood and fit together more) than I'll ever be at Chemistry.—*Elizabeth (Web site)*

Note that Elizabeth did not claim that she was not talented in chemistry, but simply that she may have been more talented in mathematics. Her decision to change to chemistry, therefore, may seem like an odd one. However, in light of the earlier comment about how "talent is secondary to passion," her decision can be better explained by exploring the domain of values.

Another talent that played a great role in this domain was interpersonal talent. Many participants placed great stock in their abilities to relate well to others, and the desire to develop this talent further in their academic and professional careers was central to their choices about their majors:

> I like to listen to others and bring up discussions, and it doesn't happen in math. I like to work with people.—*Emily (interview)*

> I think I did well in psychology because I tend to observe behaviors and interactions. Things that have to do with relating to people, I tend to do well in. I think that the people sciences, like sociology and psychology and things like that, came naturally to me in the same way that math seemed to.—*Katherine (interview)*

> I think I'll be more talented as a physician than I would as a mathematician. From what I've seen, a lot of being a physician is how you interact with people. Is someone going to trust you to tell you something? Are they going to be comfortable enough to be completely open so that you get that clue? [. . .] I just feel that my talent of dealing with people is greater than my talent at being good at math.—*Elizabeth (interview)*

In sum, for these women, their choices about their major were influenced not just by their belief about their mathematical talent but by the intersection of many talents, both academic and interpersonal.

Conflict and Resolution in Mathematical Talent

The majority of the participants had experienced little conflict concerning their mathematical talents. Although many had begun, even before the study, to question their mathematical talents (at least their talent in theoretical mathematics), many had already talked with each other about their beliefs on this issue during their debates about the role of knowledge production in the expected behavior of their departments. For those who had chosen more applied fields of study, their views of the products of knowledge were generally aligned with their views of mathematical talent as involving application skills. For those who had chosen nonmathematical fields, their views about mathematical talent were irrelevant to their field, and therefore their beliefs about whether they still possessed mathematical talent did not present a conflict. Further, these beliefs apparently had not influenced their decision to major in a nonmathematical field. Rather, their decisions were more often decisions about values.

A conflict did occur in the talent domain for one participant in particular who valued knowledge as process, as is demonstrated in the behavior of a more abstract and theoretical field, but questioned her ability to construct knowledge in such an abstract way. At the beginning of the study, Jane was strongly wedded to the idea of knowledge as process rather than knowledge as product:

> I guess I felt like it was more important to study science for science's sake. I feel (felt?) like thinking shouldn't be constrained by purpose, I suppose.—*Jane (Web site)*

Yet she also had strong doubts about her own talents in an abstract field:

> Sometimes I think I am pretty good at math, and other times I think I'm only good enough to do well in engineering.—*Jane (Web site)*

The phrase "only good enough" clearly indicated the higher position that Jane gave to theoretical mathematical talent over applied mathematical talent. Her attempt to resolve this conflict involved changing her major to a more applied field (environmental engineering), but that was not enough to give her a sense of satisfaction. It did not address her initial view of theoretical academic pursuits as more noble. Therefore, although the talent domain presented the largest source of conflict for Jane, her potential resolution of that conflict required an exploration in the domain of values.

Value

The culminating question that the participants addressed in their choices about their major was this: Do I believe those talents and behaviors are valuable for me to cultivate? In answering this question, the term *value* took on two meanings for the participants. On the one hand, they used the term to refer to an activity's desirability or usefulness in relation to career opportunities, financial rewards, intellectual stimulation, and personal enjoyment. On the other hand, they also referred to the value of an activity in terms of its inherent excellence, in a spiritual or moral sense. The first meaning of *value* had a tangible, discernable quality, whereas the second placed the term in the more abstract realm of what is right and worthwhile, based on strongly held principles and standards. The participants used both meanings as they assessed the value of their undergraduate experiences in their major departments, both in terms of their major meeting their beliefs about the purpose of an undergraduate education and the future career opportunities that their majors would afford.

The Purpose of Undergraduate Education

The value of a participant's major was often measured against her beliefs about the purpose of an undergraduate education. For example, a participant who believed that the purpose of an undergraduate education was to provide a broad liberal arts study in a variety of disciplines would tend to see an interdisciplinary major as being of great value. Their beliefs about the purpose of an undergraduate education placed the participants into two somewhat overlapping categories: intellectuals and strivers (Arnold, 1995). Intellectuals chose majors solely on the basis of their personal interests with little or no concern for career application, and strivers chose majors that both prepared them for a career and served their personal interests. There was no direct connection, however, between the type of major a participant chose and whether she saw herself as an intellectual or a striver. Consider the cases of Clara, Lola, and Nan (all mathematics majors) and their various views about the purpose of their undergraduate majors:

> I had and have no plans to use mathematics after college except for personal enjoyment, so I can confidently say that I picked math because I wanted to study it and I thought it was cool.—*Lola (Web site)*

> I don't tend to think about how I will use my math major to get a job. I just want to do pure mathematics for the rest of my life.—*Clara (Web site)*

> When I was looking at all my "major options," I inquired about the usefulness of each, and it seemed like math was the one which would give me the most options.—*Nan (Web site)*

Nan’s position as a striver did not imply that she was not interested in enjoying her major during college; rather, her position indicated that she saw her mathematical study as serving a dual purpose. Clara and Lola, on the other hand, were pursuing an undergraduate degree in mathematics purely for the intellectual gratification that it provided.

The classification of students into intellectuals and strivers can be somewhat misleading; it can imply, for example, that intellectuals are not concerned about careers. Many of the participants who fell into the intellectual category, however, were quite concerned about their careers, but they saw their undergraduate years as an opportunity to delve into academic areas that would not be available to them in graduate or professional school:

> I did the pre-med track, and wanted to major in something completely different than my science classes, since I figure I’ll be doing science the rest of my life. [. . .] I wasn’t sure if you could do pre-med and not major in science. Well, I knew that you could do it, but I wasn’t sure how it was looked on by schools. Then I thought about it a little more, and I didn’t really care how it was looked on by schools. I figured if I was going to spend four years doing this major, I better like it. I would rather do that than take a major I didn’t really care about just for the sake of looking good on paper.—*Maude (Web site)*

Other participants in the intellectual category made their choices for personal and family reasons as well as for career purposes:

> I’m planning on going to law school, and I don’t think my [history] major will severely matter. I chose it because I wanted to do what I liked to do.

> My major has nothing to do with my dream of becoming a lawyer. [. . .] Many people at my school do things because they think they are going to be useful later, and they go through classes they don't like because it will be good for them or that's because it's what their parents want or things like that. And I choose not to do that. [. . .] In a very weird way, my mother has influenced me a lot on this issue. She wanted to go to college, but because of her home situation, she could not go. So she always told us, me and my brothers and sisters, that she wanted us to be able to do what we wanted to do, and she would do her best to support us. I think I tried very hard to find out what I really wanted to do, because otherwise I would have disappointed her. She made me want to go to college, and I don't want to waste that chance. So, I decided I want to enjoy EVERYTHING about my major, and I finally found one.—*Emily (interview)*

Not all intellectuals were so directed in their career choice, but the participants in this categorization held to the idea that focusing on personal enjoyment during the undergraduate years would lead to opportunities for personal enjoyment in their careers, whatever they might be:

> My choice of major [history and science] is certainly about current enjoyment. College doesn't ever prepare you for a career very well anyway. I figure that I will enjoy it more, and learn more of the important skills "one should learn in college" by taking classes I like, by focusing on something that I enjoy, and by spending lots of time doing the extracurriculars—including sports and volunteer work—that I enjoy. Hopefully this will end up sending me into some career where I can do the same thing, i.e. enjoy my work.—*Rachel (Web site)*

For those participants categorized as strivers, their enjoyment came not just from their majors but from the variety of courses they took in other departments as undergraduates:

> I can't even stress how important I think it is to broaden yourself and take as many classes as you can. When I was interviewing, some people actually asked me, what's a math major doing with an minor in Italian? I just told them it made me well-rounded!—*Nan (Web site)*

In fact, some strivers expressed some frustration when the requirements of their career-oriented majors interfered with their interests in other fields:

> I think my degree has certainly made my life a little bit easier than [that of] some of my friends, because I have a direction for my career and some sort of aim. But one of my most boring semesters was one where I was taking two math classes, two engineering classes, and physics. It was all the same stuff.—*Hadley (interview)*

Regardless of whether the participants considered themselves strivers or intellectuals, there were two common themes in their views about the purpose of an undergraduate education: enjoyment in their fields and academic variety in being able to study in other fields. The variety of coursework, in particular, gave them the confidence and flexibility to consider a wide range of career options, such as doctor, lawyer, artist, environmental engineer, teacher, actuary, architect, and university mathematician. This confidence and flexibility also carried over into their beliefs that they could change their minds at any time during their academic or professional careers:

> Even though I am not very concerned about what kind of life I will lead in 10 years, it's only because I think that, no matter what I am doing, I'll find a way to make it fulfilling. And if I can't, I'll change my life.—*Jane (Web site)*

> The best thing though is that I know if after three years or something, I don't like where I am or what I am doing, I can always change. That's the beauty of being a young professional right now…no one with skills is

> stuck anywhere. I feel like, growing up in this generation, I have a lot of options available to me all the time, and I'm not adverse to exercising those. [. . .] I just want to always grow, whether it's intellectually spiritually, or personally…I want to be always changing and growing. I don't want to be static in anything.—*Nan (Web site)*

In sum, the participants' choices about their major were aligned with their views of the purpose of an undergraduate education, and their views of the purpose of an undergraduate education were aligned with their view of the flexibility they had in their academic and professional careers.

Career Choices

As mentioned before, even the participants categorized as intellectuals were making (or saw that they would eventually make) choices about their careers:

> I guess not all people have to draw boundaries around what they learn. Someone has to write encyclopedias. But eventually we've got to earn a living, right?—*Esther (Web site)*

Even those who chose majors vastly removed from their planned careers had still put a great deal of thought into whether their career plans would allow them to make that choice. Therefore, despite the assertion of some participants that there is little connection between college and the real world, the choices that the participants made in college were affecting (and were affected by) their career goals. In fact, the question of what they were going to do when they graduated received a considerable amount of attention in their discussions on how they chose their majors. The relationship between their majors and their career choices held great value for them, both in terms of financial compensation and social responsibility.

Financial value of career choice. The participants held a wide variety of opinions on whether the potential for high financial compensation in their career had affected their choices about their majors. No participant pointed to financial rewards as being a central reason for choosing a major and a career, but some described it as a welcome benefit:

> As far as choosing engineering, I think that was because I love applied math, and engineering was the best way that I could do that and still be able to build and design anything. Of course, because of today's job market, it is a lucrative area, which is not a bad thing.—*Hadley (Web site)*

> I've always been driven to success, and with math, I know that I can use it as a tool to help myself have a good career and make a good living, which are things that I want.—*Nan (Web site)*

These same participants acknowledged not only that a high salary was not automatically connected with a particular major but also that the benefits of a high salary were not as important as having a career that you enjoy:

> I'm going to be an actuary, so I'll have more financial rewards than some other people, but if you're a math major, you can also be a teacher and not make as much money. So, I don't think that the financial reward comes hand in hand with math. However, most people wouldn't want to do a job just because it would make them money. They would do it because they enjoy it (hopefully).—*Nan (interview)*

> I definitely think that liking what you do is more important than knowing exactly what career you're going to have and how much money you will

> make. I've met unhappy lawyers and happy social workers who are happy just because they look forward to going to work everyday.—*Knox (Web site)*

Other participants directly dismissed the notion that financial compensation had anything to do with their choices about their majors and career preferences:

> Money isn't important to me.—*Clara (Web site)*

> I've encountered a bunch of people who think that [the fact that I'm going into teaching] is cool, but say that I'm not going to make any money. They say, why don't you put your talents and skills into something else that will make you more money? It makes me think of my dad saying, "You're not going to make any money." My dad took me to the library to look at books on careers that have to do with math, and he would point out the salaries. [. . .] I like teaching too much to care about how much it pays.—*Katherine (interview)*

Katherine's last comment is somewhat misleading. She later expressed concerns about what she believed was an erroneous association between the perceived nobility of a profession and a low salary. She also indicated that she was limiting her job search to states with highly competitive teacher salaries and active teacher's unions. She still held to the notion that she was going into teaching because of her love for the profession, but she also felt that she should be able to teach and make an adequate (albeit modest) living. Although participants such as Katherine may have claimed not to have been directly motivated by the potential financial value of their majors and careers, she was aware of financial realities.

Another dilemma faced by some participants was that of not wanting to be concerned about financial gain but needing to pay off large financial obligations incurred during their undergraduate studies:

> I think a big part of it has to do with money. It feels a little dirty to sell my brain to a corporation (in engineering). I'm not much of a fan of big companies I guess, and the thought of schmoozing with corporate types for lots of money didn't appeal to me. But I decided to do something to make sure I could pay off my college loans, and then I can explore other career options.—*Jane (Web site)*

Although Jane's comments about her career path were somewhat bleak and her financial obligations were taking priority in her choices at the moment, she was unwilling to give up on the idea that she could find a career that she enjoyed:

> If I don't like my job, I can just quit and do something else.—*Jane (Web site)*

Her comments struck a chord of common feeling among all of the participants. Although potential financial gain may have played some part in their choices about their major and career, it was secondary to the potential gains from personal enjoyment.

Social value of career choice. A consistent theme in the online discussions was the value that the participants placed on the enjoyment of their majors and their prospective careers. It was essential to all the participants that they love what they do:

> You need talent if you are to succeed. But I had far more talent in mathematics than I do in chemistry…but in chemistry I have the passion.—*Elizabeth (Web site)*

> It would be boring and unfulfilling to get a job in an area you are great at but have no passion for.—*Katherine (Web site)*

If passion was such a driving force in how these women were making their choices, then what were their passions? The overwhelming majority stated that they were passionate about how their work related to their place in and effect on the world. As expected, this passion carried a large desire for personal fulfillment that often outweighed (but was still related to) their desire for professional fulfillment:

> I really feel that the way you are in your personal life affects the way you are in your professional life. Professional growth gives you status and gives you money, but personal growth gives you more happiness and overall fulfillment, which I think is important.—*Nan (Web site)*

> The personal aspect of my life is definitely more important, in that I think a good professional life will come from that.—*Rachel (interview)*

In other words, a fulfilling job and a happy personal life are connected events, and it would be difficult to have one without the other. However, the fulfillment that the participants hoped to experience in their personal and professional lives was not centered only on the self. Rather, their desires were more often affected by their perceived connection to the world and the people in it:

> I don't think I could feel good about succeeding in my field if I couldn't see it in some sort of wider context. I've said this a lot, but some concrete result, which has a tangible impact on the people around me, has become important. And hopefully I'll make a positive impact in my career. It's all about people, right?—*Esther (Web site)*

Esther's comment spoke to two essential elements in the social value that these women placed on their majors and careers. First, did they believe that the effects of their work would be tangible? Second, did they believe that the tangible effects of their work would have a positive impact? The first question spoke to their need to have a hand in (and some control over) the results of their work:

> I don't see myself working thirty years on a research project. Having the only fruit of my labor being that I discovered this phenomenon…not understanding the impact of my work on the world. I thought about the long-term usefulness of physics, and realized that physicists don't have much say in their work is ultimately used for. They discover things that other people use. I decided that I wanted to have more of a say in the consequences of my work, and so engineering would let me do that. I sort of imagined myself as a physics major ending up in an engineering job anyway, so I decided to admit that I wanted to go into a field where I could make some impact.—*Esther (Web site)*

Along with the added sense of control received from applied work, however, came added responsibility:

> I like knowing that I am going to be able to do something useful when I grow up, but someone will give me a certificate in May that says I can go build something. If I make a mistake, someone could die or something bad could happen. That scares me to death. I feel completely capable in what I do and that I know my subject well, but at the same time, knowing that I'm responsible for someone's safety is scary.—*Hadley (Web site)*

Although not everyone's feelings of personal responsibility were connected to such grave consequences, almost every participant wanted to take responsibility for making sure that the tangible work that she did would have a positive impact on people's lives. This concern addressed the second question stated above:

> You can blindly work for a corporation, or for the government, doing nuclear physics, but you realize that you would inevitably end up working with some sort of administration, and there are people who are going to do things with what you make. The research that you do is going to have consequences. It started to matter to me a little more about the consequences of what I was doing instead of just being happy. If I'm an architect or a civil engineer, I may be able to channel my social ideals into my career, which is why it is so appealing to me. Maybe do architecture that is environmentally conscious, or work on mass transit in some sprawling city.—*Esther (interview)*

> Becoming a doctor is such a worthwhile thing to do. You know that you can really help people with their lives, especially with public health and healthcare in the developing worlds.—*Rachel (interview)*

> I used to work with Amnesty International, and a lot of the people that I met there were doing careers that they were going to relate to the work that they were doing with AI. I started to think, if I'm going to spend that much time on anything (and I will be spending a lot of time on my job), I'd feel a lot better about it if I was spending that much time on something that I believe in. I feel like if I'm going to try to come up with innovations or work on something, I want it to better things…I want it to help people more than it hurts them.—*Jane (Web site)*

Jane's position is particularly interesting, given that she had earlier stated that she felt that "thinking shouldn't be constrained by purpose." Although she had originally held to the values of theoretical scientific study, her views on that matter were overtaken by her belief that her work should have positive social value.

In the light of previous research, the comments that these women made concerning the importance of a positive social impact from their work were not very surprising. Eccles (1985) cited several studies indicating that males students tended to be more thing-oriented (i.e., interested in manipulating objects and understanding the physical world) and that female students tended to be more person-oriented (i.e., interested in understanding human social interaction and concerned with helping people). The women in this study, however, indicated through their discussions of their choices about their majors and their career plans that this polarization does not apply to everyone. All three of the women quoted above, as well as many others, were simultaneously interested in understanding the physical world and in using that understanding to help better the human condition. In short, their enjoyment of science did not imply an objective, disconnected stance on knowledge. Rather, the participants held the position that there is no such thing as pure, unadulterated knowledge for knowledge's sake:

> Whether or not people acknowledge it, I think everything and everyone has some sort of social impact, and so for me, it makes more sense to strive to have a positive one.—*Hadley (interview)*

Their positions on the importance of social value in their majors and career choices indicated not so much a social orientation, which can vary from individual to individual, as a social responsibility, which is an inevitable consequence of human existence. In sum, the participants did not claim to be on one side of the person-thing dichotomy, but rather implied that the dichotomy did not exist.

Conflict and Resolution Concerning Mathematical Values

The issue of the values associated with mathematical study (particularly the social values) presented the greatest source of conflicts for the majority of the participants in the study. The very characteristic that had attracted most of these women to mathematics in the first place—its objective nature—was now driving them away as they began to question the usefulness and existence of pure, objective knowledge:

> I think in eighth grade or so I went through this phase where I thought there was no point in thinking about anything in the social sciences since you couldn't find an "answer" to them. Then I think that I developed a sense of social responsibility and it started to matter again. I sort of regret not paying as much attention to that side of things.—*Esther (interview)*

For some participants, this dilemma about the value of mathematical study undermined their previous considerations of mathematics as a possible undergraduate major:

> I decided that though I tend to think abstractly, I wanted to be in a more practical field with more concrete applications than math or physics. That was a value judgement. There's enough math in engineering to keep me happy, and I think I will be happier in a career that makes a tangible impact on the world.—*Esther (Web site)*

> It wasn't really gratifying being a math major. I mean, people thought I was really smart, but that's superficial. I saw what I was doing as almost selfish. I wasn't doing anything to help anything or anybody, and I was just playing. Spending all this time playing, and everyone telling me how good I was at playing. So I couldn't see it being a gratifying or satisfying life, just playing.—*Elizabeth (interview)*

None of these women questioned her ability or even her enjoyment of mathematical activities. Elizabeth, in particular, spoke quite eloquently about her love of mathematical proofs and the insight she felt they gave her into the inner workings of the discipline. Elizabeth and others, however, were unable to reconcile their sense of enjoyment and wonder with the fact that they did not believe that pure mathematical study would serve any useful, valuable purpose.

Not all participants, however, resolved their conflict with the values of advanced mathematical study by leaving the mathematics department. Some simply chose applied mathematical fields for their careers:

> Math as a subject doesn't have too many flaws. I guess the only thing would be that once you get higher up in the profession, people become so specialized that only five to ten people in the world can actually understand what you are doing. This is frustrating to me because it makes it hard to see why doing that level of mathematics can really make a difference or impact anything universal. That's why I like applied math, and the career that I have chosen is all applied math.—*Nan (Web site)*

The most popular choice of mathematics majors who had a conflict with the values of pure mathematical study was to go into teaching:

> I don't get it when people say I should make better use of my talent in math, because what better way is there than to help other young people?—*Katherine (interview)*

> I would love to be proud of what I do and what it does for society. I would eventually like to become a high school teacher, because there are few things more exciting to me than helping someone understand math. I love math and so I love helping people appreciate it and understand it, especially when they are frustrated and getting ready to give up.—*Hadley (interview)*

> I thought a lot about studying and teaching math. I could teach math in high school but not at the college level.—*Rachel (interview)*

Rachel's comment is interesting, given that she made some of the most substantive statements about the friendly, supportive nature of her mathematics department and mathematics professors. If she valued teaching as a socially worthwhile venture and saw her mathematics professors as having other supportive, socially worthwhile qualities, then why did she not consider becoming a mathematics professor herself? Why was there still a conflict? The conflict for her and others like her lay in research. Although the participants were often the beneficiaries of quality undergraduate teaching, they also believed that teaching was not the focus of their professors' work:

> You don't just teach when you are a professor—you are expected to research.—*Esther (Web site)*

> I could never do research, because I don't feel that it is as rewarding as helping someone learn something that you enjoy.—*Hadley (interview)*

In other words, these participants believed that the essential function of a college professor was to do research and that mathematics research was too removed from any realistic application to hold value for them. The fact that mathematics professors were often good teachers and mentors was viewed as a fortunate circumstance in university environments that value the products of research (i.e., publications, grants, etc.) and that award tenure based on those products.

In conclusion, the domain of values held such an important position for these participants that a major or career that did not satisfy their sense of values was unacceptable, even if a participant was comfortable with the environment and behaviors of that field and was confident in her talents in that field. Multiple examples of this phenomenon were evident when the participants considered the value of majoring in mathematics. Even for this group of mathematically talented women, a conflict in the domain of values alone was enough to cause some to leave the field of mathematics altogether.

Individual Participants

Although the collective data from all of the participants indicated that the model was a good fit to the data, the theoretical power of the model can be greatly enhanced by its ability to work when describing individual cases. Any participant could have been chosen to demonstrate how this model applies to the individual, but I chose three participants who provided exceptionally rich data. Even though each of these stories demonstrates a different point of conflict, resolution, and departure (if any) from an undergraduate mathematics department, they all address the essential questions of the model of academic choice stated at the beginning of this chapter.

Katherine

Katherine was a senior mathematics major at a moderate-sized university in the Northeast. In addition to her major in mathematics, Katherine was graduating with a second major in psychology. After graduation, she planned to attend graduate school and work toward a master’s degree in mathematics education so that she could pursue her dream of becoming a high school mathematics teacher. Despite multiple conflicts in all domains of the model of academic choice, Katherine had remained in the mathematics department throughout her undergraduate years. Her point of departure was when she decided not to pursue the study of pure mathematics beyond graduation.

How comfortable am I in the environment of my major department?

Katherine credited much of her discomfort and conflict with the environment of her mathematics department to the professor in her first advanced mathematics class, abstract algebra. Given that it was her initial exposure to more rigorous mathematical content, the experience had a strong impact on her view of her department:

> Every time I went to the professor for help, he didn't want to help. He actually recommended that I drop the class because I was the only girl in it and wasn't doing well. So basically I was screwed and almost failed the class because of the professor. *(interview)*

It was particularly important to Katherine that her academic environment involve quality instruction because she attributed much of her enjoyment of a subject to good teaching:

> Liking math has a lot to do with having good professors, since they are what make the material interesting in the first place. *(Web site)*

She realized that if she was going to remain in the department, she would have to find more supportive professors.

Although Katherine found her abstract algebra course and the professor to be very inhospitable, she did not extend this ill feeling to all of the professors in the department. She also acknowledged, however, that this individual was not necessarily an anomaly:

> The [professors] that I found after this evil one were really helpful to me. I could have had professors that were even worse in the department, but I tended to avoid those classes if possible. *(interview)*

Although Katherine did not find every aspect of the environment of her undergraduate mathematics department to be hospitable, she was able to find enough support from individual department members to make her comfortable with the quality of instruction there. In other words, she did not assume that this particular "evil" professor was representative of the professors in the mathematics department. His lack of interest in the class and his students, as well as his comments concerning her mathematical ability as a woman, set him apart in a very negative way from the majority of professors that she encountered during the remainder of her college career.

What kind of behavior is expected in the department in order to be successful?

Katherine's greatest conflict in the behavior domain had to do with proofs. She strongly questioned whether they were a productive use of her academic time. She also acknowledged, however, that much of her view of proofs had been determined by her experience in her abstract algebra course:

> I think I hate proofs so much because I was introduced to them in a horrible class with a horrible professor and a horrible book. Although I still think proofs would not have been my thing even if I had had a good professor. I like doing a problem and getting an answer and knowing it is right, no two ways about it. That is partly why I hate proofs—you never

> know if you are “right” or not. [. . .] If you are doing a “simple” proof, then you can figure out if you are right because you know what you are proving well enough to know that you have indeed provided enough detail and your steps are logical. [. . .] If you are trying to prove something you are not as familiar with or that you are not certain is true, you can come up with proofs that to you appear correct, but in actuality have flaws. *(Web site)*

In other words, simple proofs, while easy to evaluate were not interesting; yet the correctness of more interesting and complicated proofs could not be assessed. Katherine was genuinely interested in many of her courses that involved proofs, however, and she did not question the presence of proofs in a course that provided her with clear guidelines and expectations:

> I slowly began to enjoy proofs more because I had better professors [. . .] who were responsive to my questions. Also, I was taking classes with proofs that were more interesting to me. *(interview)*

Although Katherine did have some conflict with the use of proofs as the primary behavior expected in a mathematics classroom, the conflict resided more in the ambiguous use of proofs in poorly taught classes than in the nature of proofs themselves. Just as in the environment domain, much of her resolution of the conflict she experienced with the behavior of her mathematics department depended on her perception of the quality of her professors.

Do I have the necessary talent to be successful in the department?

Given the strong emphasis that Katherine placed on quality mathematics instruction, it was not surprising that her experiences with poor professors were often connected to moments in which she doubted her own mathematical talent:

> I struggle a lot in my math classes, since I am one of those people who has difficulty with proofs. I almost dropped math my sophomore year due to a bad/hard class experience, but then I regained my senses. But I think it might have started me off with the wrong attitude. I ended up thinking I couldn't do the math, but really I could. *(Web site)*

Interestingly enough, Katherine's conflict over her own mathematical talent was not resolved simply by receiving better instruction, as in the other domains. The better instruction certainly was an element in her feelings of success and competence, but her beliefs about her own mathematical talent carried a strong internalized component as well:

> I was successful because I persevered in the face of failure and an evil professor. *(Web site)*

> Up though high school, I just formed this idea in my head that I was talented in math because I enjoyed it and the ideas made sense to me. If I am given enough time and left by myself, I can figure it out. I do think I encountered more struggles in college with math than I used to, but I like to think that I am still talented. *(Web site)*

> If something challenges me and I feel like I got this integral understanding of what was going on, then that is where I would feel the most successful. *(Web site)*

For Katherine, talent involved internal characteristics of ability, effort, enjoyment, and integrated understanding, but the opportunity to develop that talent depended heavily, once again, on the quality of her professors.

Do I believe those talents and behaviors are valuable for me to cultivate?

Obviously, Katherine placed great value on quality teaching, which was not surprising given her plan of becoming a high school mathematics teacher.

> In fifth grade, I decided I wanted to be a teacher, and I've wanted to be a teacher ever since. A lot of times in school, the math would become simple for me, but then I would help other people figure it out, and I wouldn't get bored. *(interview)*

Asked how valuable her undergraduate major was to her and to attaining this goal, her answer went both ways. On the one hand, she said her undergraduate major was intensely valuable because it served as an essential step in her pathway to becoming a mathematics teacher. To this end, she would be categorized as a striver:

> I guess I am the only one here who would be willing to sacrifice enjoyment for long-term usefulness. I think that it is important to do something that you enjoy, but if math was the most horrible subject ever in college and I still wanted to be a high school math teacher, I would sacrifice the enjoyment of having a fun major for the chance to pursue my perfect job. I want to be a high school math teacher, so my majors seemed appropriate to me. [. . .] I suppose I ultimately chose math because I knew it would benefit me in the future, but I went into college deciding to major in math because I liked it. *(Web site)*

Although Katherine admitted that she did find some inherent enjoyment in studying mathematics, even at the college level, she also still held to the belief that the value of her undergraduate major came from the career opportunity that it provided. Also, her enjoyment of teaching mathematics far outweighed her enjoyment of doing college-level mathematics:

> I'm a big "people person," in conjunction with my skills in math. I can be incredibly patient when I am trying to help someone understand something. The people who don't get it, and how do I help them to understand it? That is why I like teaching. *(interview)*

Given this strong focus on career preparation in her undergraduate education, it is likely that Katherine would have majored in mathematics education rather than mathematics had it been available at her university.

On the other hand, Katherine said she found little value in her undergraduate mathematics program, in that it provided her with few models of quality teaching:

> Most of [my professors] have no social skills at all. [. . .] I find that at my university, there are many professors who are brilliant, and everything comes easy to them…they just understand everything. But they just can't teach. *(Web site)*

It was no surprise, then, that Katherine could not see herself teaching at the collegiate level given that she believed that college professors were not focused on the professional characteristics that she valued the most: an ability to provide quality mathematics instruction and a desire to help others understand and enjoy the discipline.

Although Katherine's choice of undergraduate major was intensely valuable to her in a career sense, it was not valuable to her in a more general, abstract sense. She did not see professional university mathematicians to be focused on the interpersonal connections that she found so important for her career.

Jane

Jane was a sophomore at a moderate sized university in the Southwest. When she began the study, she was majoring in physics with a second major in art. During the study, she changed her major from physics to civil engineering, maintaining her second major in art. She then considered dropping her second major so that she would have the time to take the extra classes required for a concentration in environmental engineering (an new option available in her civil engineering department). Jane had some regrets about leaving the physics department, and much of her conflict and resolution dealt with her desire to allay her misgivings about the change.

How comfortable am I in the environment of my major department?

Jane had very few if any conflicts with the environment in either the physics department or the civil engineering department. In some ways, she found the civil engineering department to be more hospitable.

> In the physics department, I had one professor in the first year that I was at the university who was really good, which was probably why I wasn't discouraged immediately. Also, the physics department head was really nice to me and took a personal interest in me. [. . .] When I switched, I found that the civil engineering department was also very close—both the faculty and the students. They're some of my closest friends now, and I've only been there semester. It's definitely a closer department, and maybe even friendlier. *(interview)*

Therefore, the misgivings that Jane had about her switch to civil engineering were not associated with professors or peers in the environment of the engineering department.

What kind of behavior is expected in the department in order to be successful?

Jane had few misgivings about the behavior that was expected of her in either the physics department or the civil engineering department. In fact, she noticed very little difference in the expected behaviors of the two departments, as both focused on group work and lab projects.

> Every once in a while, I see my old physics group working, and it looks really interesting, because they're into modern physics, one of the most interesting classes you can take. I'm not taking it, and I get a little bit jealous. But the civil engineers, we have amazing group interactions. We were all trying really hard to make sure that we do our part. I guess a lot of it was because we interacted well as friends. It's like letting your friends down, not showing up to work in the lab. *(interview)*

Although Jane saw little difference in the expected collaboration on lab work between the two departments, she saw a difference in the purpose of the labs, as physics focused more on abstract concepts and engineering focused more on applications and mechanics. Jane enjoyed the mechanical aspect of her civil engineering labs, but she also enjoyed the abstract concepts of courses such as modern physics. Therefore, the difference (or in this case the lack of difference) in expected behaviors between the two departments presented little conflict in her choice to change her major.

Do I have the necessary talent to be successful in the department?

In the domain of talent, Jane first began to experience a conflict in her feelings about her change of major. While she had been in the physics department, she had enjoyed both the department and the work that she was expected to do. She had come to strongly doubt, however, her ability to be successful in that environment:

> There is a lot of thrill when an abstract concept "clicks," which is why I was doing physics. But I decided that at upper levels, this "click" wouldn't be attainable for me. I'm not sure I'd be able to conceptualize particle physics the way I can mechanics. I think, actually, it's because I don't have a whole lot of confidence in myself in [physics]. Also, I was intimidated by how bright the other physics students and faculty are. I feel like I'm good at it, and someday I feel like I could be decent at it, but I don't think I could be excellent, and I really need to feel like I'm excellent at something. [. . .] I don't feel like I'm smart enough to make much of a difference in an abstract field, but I feel like I am smart enough to make a difference in a something practical, like environmental engineering. *(interview)*

That Jane felt that she was more talented in engineering than in physics did not in itself present a conflict. In fact, it may simply have been an indication of her willingness to evaluate and assess her own academic strengths and weakness. The conflict arose because Jane believed that the knowledge she had gained from studying physics and mathematics was somehow more valuable than the knowledge she would gain from studying engineering. Subsequently, she also felt that the ability to do physics represented a higher plane of ability:

> I feel like the level of thinking required to do math and physics is higher than I can handle, and the level of thinking required to use math and physics is lower than I want to deal with. *(Web site)*

Jane had changed her major not just because she had begun to doubt her abilities in physics but because she had begun to doubt her academic abilities in general.

Do I believe those talents and behaviors are valuable for me to cultivate?

Jane placed great value in the intellectual pursuits and products of abstract scientific study (particularly physics), almost to the exclusion of other fields of study. It is unclear why she felt that pure scientific inquiry was more valuable than other fields of study. Some of her belief system was evident in her view of research in abstract fields of science as the antithesis of research done for a corporation, which might use the products of her knowledge for financial gain:

> I don't know if its because my family is really liberal, but I feel like lots of times industry is really only working for profit, and I don't feel like I want to work for someone's profit. I don't even want to work for my profit! If I work for a university, then I can do research on something whether it's going to make someone a profit or not. [. . .] Now I've sold out to engineering. But I decided I needed to do something to pay off my college loans. But one of the things that I'm worried about with being an environmental engineer is that if I go to a corporation that's not environmentally friendly, that they just hired me to barely make the regulations, or to work around the regulations. Or maybe I'll go in and evaluate a situation where I'll give a recommendation that they'll ignore. I feel like working for a university that's doing environmental research would be more help. *(interview)*

In other words, it is unclear whether Jane truly valued the prospects and products of abstract scientific research or whether she saw that as the most salient alternative to working in industry, which she inherently distrusted.

Another feature of the value Jane placed on pure science was the academic prestige it provided:

> I think I did get a kick out of the respect that I got for being a physics major. It is an easy way to get noticed at a reasonably sized and good school. And at my school, saying that you're a civil engineer doesn't come with that much prestige because it's kind of one of the less intense engineering areas. My dad puts a lot of pressure on prestige also. That might even be the reason why I'm doing math and science in the first place. *(interview)*

In sum, while Jane claimed to hold in high regard the values of abstract scientific study in physics, it appeared that many of the reasons for the value she put on advanced study in physics (such as political beliefs, financial issues, and family pressure) had little or nothing to do with the discipline itself.

After Jane had changed her major from physics to engineering, did she then value the pursuits and products of advanced study in engineering? Certainly. Although studying physics implied certain abstract, intangible values, those values were outweighed by her belief that studying and pursuing engineering as a career would eventually have a greater positive impact on the world:

> The only thing about [physics] is that it doesn't usually have immediate results for society or for people. I would like for my job to involve cool people and be intellectually challenging and interesting, but ideally I'd

> like to think it was worthwhile too. [. . .] What I learn is never as important to me as personal relationships and helping people in some way. What I study is just the means for attaining that goal. *(Web site)*

That Jane wanted her work to have a tangible positive impact was not surprising given her earlier expression of dissatisfaction with the idea that her work might provide only financial gain. The shift in values represented not an after-the-fact rationalization but rather an acknowledgement of a preexisting belief system. Regardless of when and why the focus of her value system shifted, Jane's beliefs about the possible positive benefits of studying engineering indicated an acknowledgment that to feel satisfied with her choice to change majors, she had to reconcile her academic environment, behaviors, talents, and values.

Elizabeth

Elizabeth was a junior at a large technical university in the Southeast. As part of a highly talented mathematical family, she had been exposed at an early age to many of the logical bases of mathematical thought. In high school, she was already enrolled in graduate level mathematics at a local university. She had always considered it a certainty that she would pursue a career as a professional mathematician. She entered college intent on majoring in mathematics, but late in her sophomore year she changed her major from mathematics to biochemistry. According to Elizabeth, her decision to change her major was strongly motivated by her realization that she wanted to pursue a career in medicine.

How comfortable am I in the environment of my major department?

Elizabeth had no conflict with the environment in either the mathematics department or the chemistry department. She found her professors and peers in the mathematics department to be supportive and affable, but she had no difficulty transferring that feeling to her new department:

> I made lots of contacts in the chemistry department. I'm good friends with a lot of the grad students now. I'll just walk around the halls and hang out with professors, who I know on a personal basis. If I need something from someone, like a recommendation, it's there. Or if I need advice or something, I can just sit down and talk with people. *(interview)*

Elizabeth also cited the good relationships that she established with her professors as one of the reasons that she had been able to take advantage of opportunities in the chemistry department:

> I was walking around one day, and I decided, hey, I want to work for that guy. That's kind of interesting stuff. So I just went up to him after class and said, "I want to do some research this summer. Do you have any funding?" *(interview)*

This proactive approach to her relationship with her professors helped her gain a position as the only undergraduate research assistant on a National Science Foundation funded research project at her university.

What kind of behavior is expected in the department in order to be successful?

Not surprisingly, Elizabeth saw the predominant element of the expected behaviors in the mathematics department to be proofs. She had no conflict with doing proofs, however, and actually found them to be one of the most exciting, invigorating parts of her university mathematics study:

> Math is beautiful! And you don't really understand that until you write a proof about it. And you say…ahhh! You start to understand how it works together, [and] not just [that a] proof is true. . . .In the writing of the proof, you start understanding the character, how the system behaves. You get this picture of it. It's beautiful. It's like this whole other world that you get to see. *(interview)*

Elizabeth did not shy away from the pursuit and creation of abstract knowledge. In fact, as far as she was concerned, the more abstract the better:

> My favorite calculus was vector calculus—seeing things that are hard to see. *(interview)*

Working in the chemistry department presented a different kind of behavior (namely, laboratory research), but Elizabeth still found herself drawn to the abstractions behind the research:

> The beauty of science is that we are trying to simplify. We're trying on a very base level to find the unifying theory. So you want things to be as simple as possible, because the rule probably isn't all that complicated. It think simplicity is very beautiful, but it's a very hard thing to arrive at a lot of times. *(Web site)*

She also found the process of doing laboratory research intensely gratifying and creative:

> There is a lot of creativity involved in research. Nobody tells you what to do. Well, they do, but you get to use your brain a little. You don't know what's going to happen necessarily. . . . There's this whole other world that you're trying to get a handle on, [and you're thinking,] "How do I explore this world? It's so small!" *(interview)*

In sum, Elizabeth found that the behaviors expected in both the mathematics and chemistry departments satisfied her need to explore the abstract, intangible concepts that were so important to her own sense of knowledge.

Do I have the necessary talent to be successful in the department?

Elizabeth never questioned her talents or ability to be successful in the mathematics department. She also saw herself as talented in chemistry, but she readily admitted that she felt that her mathematical talent came more naturally to her than her talent in chemistry:

> When I was doing math in high school, I was in all these graduate courses, and I didn't have to work at all. It always just came easier. That's just the way I think. I still find myself saying, "Why did I switch to chemistry? I was so much better at math!" *(interview)*

However, in addition to her multiple talents in academic areas, Elizabeth also felt that she had a strong talent in the interpersonal realm:

> What I've always been the best at are the friendships and the one-on-one. I've never been popular, so to speak, but the friendships that I have had have always been meaningful. Also, I've been told that when someone's upset or when someone's hurt, I have this way of walking into a situation where all of the sudden, they see me, and they're confident in me, that I just display this confidence that everything is going to be fine. Whether or not this is true, I don't know—I've just been told. And if that's true, it's nothing that I've done. It's just the way that I am. So, the more I think about it, the more I know that [being a doctor] is what my personality and talents are best employed in. In essence, I'm looking forward. *(interview)*

In sum, it was essential to Elizabeth that whatever academic and career path she chose should tap into all of her talents, not just her academic talents.

Do I believe those talents and behaviors are valuable for me to cultivate?

Although Elizabeth did not have a conflict with the intellectual value of advanced mathematical study, she did have a conflict between advanced mathematical study and her personal values. In short, mathematics was something that she enjoyed, but she was not passionate about it, and that lack of passion was due mainly to her view of her work in mathematics as purely self-serving:

> I had to write an essay for college about why I wanted to study math. I didn't [want to study it]. It was a game…a game I was good at, but merely a game…for me at least. It was just puzzles, and oh, this is fun. But then to say that I'm going to make this my life? I don't believe that I want to spend the rest of my life doing something that's not going to help people. The worst feeling the world for me is to feel selfish. I don't like that. And math was really selfish to me, because it was really playing. I realized my calling is medicine, so I switched majors. I would HATE being a mathematician, but I can't WAIT to be a doctor…it is all I want. I have talent in both areas, but I have passion in the road with chemistry in it. *(Web site)*

Therefore, whereas Elizabeth could certainly be categorized as a striver, her choices about her major were motivated not simply by her career aspirations but more by her desire for a career in which she could make a tangible, positive impact on those around her. Interestingly, Elizabeth was aware that such tangible impacts were possible in mathematics despite the highly abstract nature of the discipline:

> My brother is a mathematician, and he is actually doing significant work, doing stuff with land mines…tangible stuff. I don't think that I'm at that level in theoretical math. I don't believe my mind can grasp such things. Maybe I'm doubting myself, but I kind of know my limits to some extent. I've tested them. I'm not at that level at all, where I can accomplish something significant. *(interview)*

Elizabeth valued the tangible impacts of advanced mathematics, but she also valued her own assessment of her abilities, talents, and desires. Also, given the value that Elizabeth placed on her interpersonal skills, it is no surprise that she chose a field that she felt would challenge her intellectually, creatively, and interpersonally:

> It has little to do with what I was good at or what I wasn't good at. I just knew I did want to study math anymore. I was better at math, but I like chemistry more. I guess what it boils down to is, when I'm working, am I living? *(interview)*

In conclusion, although the only conflict that Elizabeth experienced with her undergraduate major in mathematics concerned values, her choice to major in chemistry did more for her sense of satisfaction than just address her sense of values. It is unlikely that she would have chosen the major if she had not also found satisfaction in the environment, behavior, and talents of her newly chosen field. In that sense, Elizabeth's case demonstrates the need for the participants' choices of majors to adequately address all domains in the model of choice.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to develop a model of academic choice that could be used to describe why mathematically talented college women choose to major in or not major in mathematics. Although mathematically talented male and female students are performing and participating at relatively equal levels throughout primary and secondary school (Arnold, 1995; College Board, 2001; Hanson, 1996), the large majority of undergraduate mathematics degrees are still awarded to men (Loftsgaarden et al., 2001). This implies that mathematically talented women are leaving the mathematics pipeline during the college years and that they are leaving because of *choice* and not because of low achievement in their mathematics coursework (Oakes, 1990). This study examined the specific factors affecting that choice.

The participants in this study were 12 mathematically talented college women from a variety of colleges and universities throughout the United States. The participants represented a wide range of majors, including fields in the humanities, fine arts, sciences, and engineering. They were recruited via electronic mail using a snowball sampling technique (Patton, 1990). All participants met a diverse set of criteria for exceptional mathematical experience, including both quantitative measures of mathematical talent (such as standardized tests and course grades) and qualitative indicators of mathematical interest (such as participation in extracurricular mathematical activities).

The participants engaged in a 12-week online focus group discussion via a Web site bulletin board. Participants could sign on to the bulletin board and post an entry or a response at any time and in any order throughout the duration of the study, but it was requested that they post an entry a minimum of twice a week. The participants also agreed to a closing interview, either in person or over the telephone, after the bulletin board had closed. The data from the Web site and interviews were collected and analyzed using the techniques associated with grounded theory methodology (Glaser, 1992; Glaser & Strauss, 1967).

The findings in this study addressed three research questions:

1. What factors affect mathematically talented college women’s choices about their major?
2. What is the relative importance of these factors?
3. How does the relative importance of these factors explain why mathematically talented women choose to major in or not to major in mathematics?

The first two questions were addressed by the model of academic choice, which stated that women's choices about their academic major could be expressed in four domains: environment, behavior, talent, and value. These domains are listed in order of relative importance, with environment having the lowest relative importance and progressing to value which has the greatest relative importance. (See Figure 1 on p. 63.) The relative importance of the domains refers specifically to how the participants responded to any conflict within the domain and the likelihood that a conflict would cause them to change their majors. When a conflict was experienced at any level (e.g., "My major requires doing lots of proofs, but I'm not very good at proofs"), a participant resolved this conflict by either reaching an internal compromise about her current major or by changing her major outright. A conflict in the environment domain often resulted in a internal compromise which did not cause the participant to leave her department, whereas a conflict in the value domain often resulted in the more dramatic decision to change majors. It was therefore essential to the participants that they experience little if any conflict with the value they attached to their major departments, as a conflict in this domain would most likely result in leaving the department.

The third research question was addressed when the general model was applied to these women's decisions of whether or not to major in mathematics. The participants had very few conflicts or concerns with the environment of the mathematics departments at their universities, and even when they did, these conflicts and concerns were not cited as a central reason they were or were not majoring in mathematics. In fact, some participants who had conflicts with the environment of their mathematics departments were still choosing to major in mathematics, implying that these conflicts were not so significant that they were unable to resolve them while remaining in their departments. The participants had many conflicts and concerns, however, with the values of the mathematics departments at their universities, and those conflicts were often cited as a central reason (and occasionally the only reason) the participant was not majoring in mathematics. Specifically, almost all participants felt that it was important that their work have a positive, tangible social impact, and the abstract nature of mathematics caused concern for a number of them. However, all participants who were majoring in mathematics claimed that they found their major satisfying in the value domain, which was consistent with the general finding that participants found satisfaction in the value domain to be essential to their overall satisfaction with their choice of majors.

Limitations and Future Research

One of the major limitations of these findings comes from the lack of diversity in the participant group. Although this group consisted of mathematically talented women from a variety of colleges, the snowball sampling technique resulted in a group that was not highly diverse racially or economically. That result is not surprising given that the women were connecting me to potential participants who were their friends and peers, who would likely be from similar racial and economic backgrounds. All of the women in the study came from a position of relative privilege, with highly educated parents, a supportive family and learning environment, and access to private secondary schools and colleges. It is impossible to say how much this sense of privilege contributed to their confidence in their abilities and allowed them the luxury of being concerned about the social implications of their work. In many ways, they took for granted that they would be successful, and therefore they were able to focus on the purpose of their success. That is not to say that a less economically advantaged group of mathematically talented college women would have responded differently, but any attempt to test this model in future research should attempt to show that the model fits (or does not fit) a more economically and racially diverse population.

There is also the question of whether mathematically talented college men would have responded any differently than mathematically talented college women. Seymour and Hewitt (1997) found that although only 28 percent of female freshman mathematics majors persisted in that major, only 29 percent of all freshman mathematics majors persisted. The problem, therefore, of the attrition of talented students from undergraduate mathematics departments can certainly not be categorized solely as a “girl problem.” Seymour and Hewitt also found that many of the issues that cause college women to switch out of SME majors are the same issues that cause college men to switch out of SME majors, implying that there is less of a difference between male students' and female students' experiences in college mathematics departments than some research has previously indicated. According to their report, "some aspects of the learning environment in which women feel most comfortable—particularly cooperative, interactive and experiential learning contexts—are also congenial to many young men." (p. 314). The participants in the present study stated that they felt that their male friends would have responded similarly to their female friends to the discussions that arose on the Web site. In fact, the suggestion was made that college-aged students would probably respond in a similar way, regardless of gender, because of the general idealism and naiveté associated with undergraduate study. Many participants, in the closing interview, made the suggestion of testing this idea by repeating the study with a group of mathematically talented college men.

The idealism and naiveté associated with undergraduate study in itself presented another limitation. The participants in this study were very young, and they openly admitted that they were currently not very concerned with issues such as raising children, paying the mortgage, and the like. They were unwilling or unable to see how these issues might affect their choices at the moment, as the issues were too far away to have immediate relevance. The participants, however, did leave the door open for change in their adult lives and careers, implying that they at least acknowledged that priorities and desires might change as they matured. A follow-up study of these women as they progress through adulthood might provide an interesting consistence or contrast between the plans and priorities of their youth.

Methodological Implications

The use of a Web site to conduct focus group interviews presented many positive benefits. When recruiting participants, I found that most were unconcerned about the potential duration and obligations of the study, because checking e-mail and logging on to Web sites was something that was already a part of their daily routine. At the conclusion of the study, many participants talked about how they liked the flexibility that the Web site offered. They could quickly check the site on a study break, but they could also muse for a while on the most recent postings before responding. The flexibility in response time also diminished the disadvantages that may have been experienced by participants whose first language was not English. The Web site program itself was also familiar and simple, so they expressed no problems or frustrations that may have been present when learning a new or complex system. As a result, the great majority of the participants far exceeded the minimum requirement of two posted entries to the Web site a week. During peak discussion periods, some participants were posting entries as often as once or twice a day. Ease of use, however, would not have been sufficient to sustain their participation for such a long time. When asked at the end of the study why they agreed to do the study in the first place, most said that it was because this issue was of interest to them, both personally ("Why did I pick my major?") and globally ("Why are there so few women in math?"). The use of the Web site as the mechanism for data collection simply made the process by which they could explore that area of interest a little easier.

The use of pseudonyms on the Web site presented positive and negative aspects. There is no question that pseudonyms were necessary in the reporting of results, but were they necessary on the Web site? Most of the participants were indifferent on this question. Given that most participants did not know each other before the study began, there was little difference, from their perspective, between responding to a person who had given a true name and one who had given a pseudonym. Some participants, however, did know each other, at least slightly, and those participants commented that the pseudonyms gave them an extra sense of security.

The security created by the pseudonyms, while desirable, may have also created a less desirable amount of distance. It is possible that the use of pseudonyms inhibited the participants' ability to connect on a more friendly, personal level. Would any of these women have attempted to stay in touch had they actually known each other's names? If so, that would have been an added benefit, given that previous research indicates that talented women sometimes feel isolated in mathematics and science departments. Although none of the participants commented on her minority status as a motivating factor (either positively or negatively), they were aware that they were often one of only a few women in their mathematics and science classes. As an example, one participant started a chapter of the Society of Women Engineers at her college, but by the time she was a senior, she was the only female engineering major in her class. Would her sense of isolation have been assuaged a little had she maintained contact with other female engineering majors from other colleges who were also in the study? Of course, there was nothing to prevent the participants from maintaining contact, but perhaps the lack of real names impeded that possibility.

The majority of the data cited in chapter 4 came from the Web site discussion group. That is not surprising, given that the discussion group lasted for 12 weeks and generated over 200 entries. The site was the place where the participants were able to formulate, discuss, and reflect on their ideas over a long time and hence contributed much data to the model of choice. The Web site also allowed all participants to take part at a relatively equal level, with no one person dominating the conversation. This fact, however, does not decrease the value of the individual interviews at the end of the study. The interview was the time where individual participants were able to emphasize, de-emphasize, change their mind, or speak their mind more openly about what had gone on during the discussion group. For example, I was surprised to learn that one of the participants temporarily dropped out of the bulletin board discussion because of comments that had been made online about a particular major. She disagreed with the comments so strongly that she felt she needed to step away for a couple of weeks to gain her composure. "I didn't want to say anything about the [other] people. …I was so frustrated!" It was only through the individual interview that I was able to find out what exactly was said and why it upset her so much. This brief conversation provided me with a remarkable look into this participant's views about mathematical knowledge that would have been lost without the closing interview. In short, the combination of online focus groups and individual interviews provided a wealth of data that would not have been obtained by using only one data collection technique.

Conclusions

The findings of this study both supported and refuted findings from previous research in this area. Consider first the model of women's talent development put forward by Reis (1998). The four elements of her model (environmental factors, above-average intelligence, personality factors, and social importance of talent development) were part of the model used to describe the experiences of the women in this study. Reis's discussion of environmental factors, however, was strongly focused on family support, which the participants in this study claimed was not a factor in their decisions. Rather, their discussion of environmental factors focused on the collegiate environment and whether they believed that environment was conducive to learning. Another interesting comparison to Reis's work is her observation that talented women very often choose to develop multiple talents rather than focusing only on one and that they take equal pride in their professional and personal accomplishments. The large number of participants in this study who had interdisciplinary or double majors seems to support that conclusion. However, the participants in this study did not necessarily take equal pride in their two majors. Many treated their second major as a pleasant diversion and an opportunity to take some courses outside of their first major on occasion. Their first major reflected their career plans, and their second major reflected a hobby or other interest.

Consider also the comparison between the findings of this study and those of the Seymour and Hewitt (1997) report. Although this study did support the contention that female students leave science, mathematics, and engineering (SME) majors because of a loss of interest in SME or a rejection of SME careers and associated lifestyles (both issues associated with values), the findings did not indicate that female students leave SME majors because of poor teaching from SME faculty. Although some participants gave descriptions of poor teaching, the overwhelming majority found the teaching they received in their major (SME or non-SME) to be of high quality. Also, those participants who did describe occasional poor teaching episodes did not change their major as a result of that experience.

It is also interesting to note, when comparing the results of the present study to those of Seymour and Hewitt (1997) and others, the potential loss of specificity that can occur when considering all SME majors together. The participants in this study clearly made a distinction between highly abstract SME majors (such as mathematics and physics) and more applied SME majors (such as environmental engineering). This distinction is complicated even further by changing views of some subjects (particularly physics) from applied to theoretical as they progressed from high school to college. Therefore, the lumping of all of these majors into one large SME category could mask some of the differences that occur in the students' perceptions of whether they are satisfied with their choices.

One central finding of Eccles' (1989) work was supported, which was that value has a greater effect on choices than expectancy. Eccles also wrote about the importance of social value in women's choices, which is heavily supported by the results of this study. Her description of social value, however, focused heavily on the social importance of spending time with family, which was not cited as a factor in their academic choices by the participants. That omission is not to imply that they had not considered the difficulties of having a career and raising a family. In fact, this issue brought about one of the most heated discussions on the Web site. Although they were concerned about how to balance family and career, they claimed that this concern did not influence their choice of major. In other words, they did not seek out or avoid certain majors and careers because they felt that the career would be difficult for raising children, which is why this factor was not included in the model of choice. The participants acknowledged that any career, even ones typically associated with working mothers (such as teaching), would present difficulties with raising children. Many spoke about searching for active solutions to the issue during their careers by attempting to change the system from the inside rather than avoiding the system altogether. The participants also acknowledged the role of a supportive spouse and partner in working through this issue of family and work, which is another finding supported by Reis (1998).

Although the findings of the present study on the social value of academic choices are supported by the literature, the findings take on a different light when considered in the context of Sternberg's (2000) concept of wisdom. According to Sternberg's model, the goal of wise choices is the desire to advance the common good, a desire highly associated with social value and social orientation. Although some research presents the social orientation of talented women as a flaw or deficit, impeding their ability to advance in mathematics (Benbow & Lubinski, 1993), Sternberg argues that this social orientation represents a strength and a desirable goal in the development of talent in any field. Using Sternberg's model, the choices of many of these women can easily be described as wise even if those choices resulted in leaving mathematics for another major. Although it is certainly possible to exercise wise choices and still major in mathematics, considering student's choices in light of Sternberg's theory of wisdom changes the outcome of interest from simply the choice of major to the wise application of that major.

Of course, these findings are most important when considered in light of how interested parties might use them to address the issue of the loss of talented women from mathematics. Consider first the application of these findings to the research community. Not only do the findings provide a new focus on the factors that influence women's choices, but they also force us to reconsider the problem of "loss" altogether. Recall that in the first chapter, the loss of talented women from mathematics was thought to have negative implications in both academic and nonacademic fields. Although the overwhelming majority of these women were not choosing to pursue academic careers in mathematics departments, a large number were using their mathematical talents in ways that address the concerns of diversity and future innovations in nonacademic mathematical and scientific fields. In short, should researchers be considering as a loss a talented college woman who changes her major from mathematics to engineering or biochemistry? Many of these women are making academic and career choices that will utilize their mathematical talent in creative and innovative ways and also satisfy their personal need to see the tangible, positive impacts of their work. A choice that allows for the development of mathematical talent and benefits the individual as well as society as a whole is difficult to categorize as a problem. That observation implies not that the issue of gender equity among mathematics faculty should not be considered a problem but rather that a young woman deciding not to major in mathematics does not necessarily constitute a problem. Therefore, the findings of this study force mathematics education researchers to be more specific about what they wish to consider a loss of talented women from mathematics. To say that talented women are not majoring in mathematics is simply not enough.

Another interested party who might find the results of this study useful are the parents of mathematically talented young women. Although I noted earlier that the privileged upbringing provided by the parents of these participants may have had an indirect influence on the factors that influenced their choices, it would be unwise to assume that privilege alone provided these women with the confidence and wisdom needed to make those choices. Bloom (1985) stated that a supportive family environment was one of the keys to the development of talent in young people, and the comments made by the participants in this study supported that claim. Why then, was parental support and influence not included as a factor in the model of academic choice? Family influence, like the concern over balancing children and career, was discussed a great deal, particularly in the interview. When asked directly, however, whether they felt that their parents had been a factor in their choice of majors, the participants said no. They described their parents as providing opportunities, support, advice, direction, and encouragement, but little pressure. The only pressure that was mentioned consistently was the desire on the part of parents for their child to choose what made her happy. One participant spoke of her father and what she felt was a slight pressure to choose mathematics or science because of the prestige associated with those fields, but that pressure was countered by comments from her mother about choosing a field that she loved. In sum, the parents of these participants provided them with the tools for making wise decisions, but in the end, the decision belonged to the child, giving the participants a sense of ownership and control over their choices. Therefore, although the parents no doubt had an impact on a participant’s ability to make wise choices, the independence and confidence that the participants felt allowed them to see those choices as their own.

The findings of this study have potential applications for the practice of attracting mathematically talented college women to undergraduate mathematics departments, through both extracurricular programs and university department recruitment. The programs operating outside of the individual university, such as the programs listed in chapter 2, have tended to focus heavily on confidence, achievement, and academic opportunity in their attempt to attract women to the field. The results of this study, however, indicate that these mathematically talented college women already have high levels of confidence and academic access. Their concerns are more interpersonal than intrapersonal as they struggle with the implications of their academic success rather than just their ability to be academically successful. That observation does not imply that extracurricular programs designed to attract college women to mathematics departments have not been successful on some level, but their success will be limited if they do not move beyond confidence and opportunity to the next level of academic values.

This issue presents a similar challenge for university mathematics departments that are concerned about the low number of students (both male and female) choosing to major in mathematics. First, consider the role that individual professors play in the decision to major in mathematics. Although one participant spoke of some very negative experiences with the professors in the mathematics department at her university, she was eventually successful in finding professors who she felt both modeling quality teaching and matched her learning style. Had she been unsuccessful in finding good professors after one “evil” professor, it seems unlikely that she would have persisted in the department. Also, had she not been so committed to her goal of becoming a mathematics teacher herself, then her experience with the ineffective professor might have been enough to cause her to change her major.

As a counterexample to that participant’s negative experiences with the professors in her university’s mathematics department, a second particicnpant’s story emphasizes the positive impact that mathematics professors can have on student’s choices. When this particpant entered college, she was considering a wide variety of majors. She had certainly excelled at mathematics in high school, but she excelled at all subjects, and there was nothing about her experience with mathematics that made it rise to the top of her list of options. When she entered college, however, she found herself being actively recruited by the head of the mathematics department, and it was this personal interest, in combination with the information that he provided about possible careers available to mathematics majors, that she claimed started her on the path to choosing a major in mathematics. Although these experiences with mathematics professors would fall into the domain of environment in the model of academic choice, the experiences of the participants with the professors in their mathematics departments indicates only that environment is a factor of low relative importance, not a factor that is unimportant.

How might undergraduate mathematics departments use the findings of this study indicating that values are the most important factor in talented women's decision whether or not to major in mathematics? Much of the decision rests with the impressions that students form of the values of a mathematics department in the first years of undergraduate study. If a student does not have the impression within the first two years of college that a major will be satisfactory in the value domain, then she is unlikely to make that major her final choice. Considering that many of the participants viewed the first year of college mathematics as consisting of "weed-out" survey courses, it is not surprising that very few saw an undergraduate major in mathematics as an attractive option. They were already concerned about the relevance and social implications of their academic work, and their early mathematics courses provided few indications that mathematics met these concerns. Instead, these courses, as well as many subsequent courses, focused almost entirely on proofs rather than relevant applications.

These findings are similar to those of a recent study of female undergraduate computer science majors at Carnegie Mellon University (Margolis & Fisher, 2002). The researchers found that female students were drawn to computer science because of what they perceived as the positive social implications of computing innovations, yet their experiences in their early computer science courses focused almost exclusively on programming. As a result of these findings, Carnegie Mellon made serious changes in the structure and curriculum of their undergraduate program in computer science. One of the changes put in place was the institution of an "immigration course" (IC) for students entering the undergraduate program. Previously offered only to incoming doctoral students, this course was designed to provide students with a broader, contextualized view of the field than they tended to received in their early programming-oriented courses. As a result of the new course, freshman and sophomore computer science majors who had participated in IC had a much clearer view of the field and its applications than students who had not had the opportunity to participate in IC. As a result of this change as well as many others (including student recruitment efforts and increased focus on quality teaching), the proportion of women entering Carnegie Mellon's undergraduate computer science program rose from 7 percent in 1995 to 42 percent in 2000. This dramatic change in the proportion of women in a department speaks to the power of early efforts to place undergraduate coursework within a broader context.

The findings of this present study support the idea that undergraduate mathematics departments could also benefit from instituting such an “immigration” opportunity for their students that focuses on the social implication and value of mathematical work. Although it is true that undergraduate mathematics departments have to some degree always addressed the issue of the value of mathematical study, much of their emphasis is on the aesthetic value of the subject—the inherent beauty of mathematics and the pursuit of knowledge for knowledge’s sake. This aesthetic value was certainly important to the women in this study, as they were unlikely to pursue a field that they did not find enjoyable on a personal, intellectual level. However, equally if not more important to these women was the value of their work in context. How was their work going to affect the work of others? If the culture in their major departments was not able to provide an answer to this question, then they were less likely to remain in that department. This view challenges undergraduate mathematics departments to place early emphasis on not only the intellectual value of mathematical study but its social value as well.

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APPENDIX A

PARTICIPANT RECRUITMENT LETTER

To:
From: Lynn Gieger <jgieger@coe.uga.edu>
Date:
Subject: dissertation at UGA

Dear [ ] --

Hi...my name is Lynn Gieger...I'm a grad student in mathematics education at the University of Georgia. I recently contacted a mutual friend of ours, [ ], and she was kind enough to give me your name as someone who might be interested in participating in my dissertation study. In a nutshell, I'm looking at mathematically talented college women and how they came to choose their college major. There is lots of literature out there saying that mathematically talented women aren't majoring in mathematics (or mathematics-related fields) nearly as much as mathematically talented men, but the conclusion of most of these studies is that mathematically talented women are somehow missing the boat. I, however, think this conclusion is a little too simplistic. That brings me to my central reason for the study...there really isn't anything out there that attempts to explain the choice behavior of women. Rather, the choices made by women are often compared to those made by men. The fact is, there are plenty of mathematically talented college women who are majoring in mathematics-related fields, and to simply say that there aren't as many women as men in these fields does not provide any illumination on the issue of HOW talented women choose their major. Of course, an essential part of this study is that college women from a number of majors (both mathematical and non-mathematical) are part of the discussion. Where exactly you see yourself on the math/non-math spectrum is completely up to you...your input would be valuable in any case.

And now onto the nitty-gritty...what would you have to do if you decide to participate? Almost all of the data in this study will be collected on-line, through an internet bulletin board and e-mail. The bulletin board is where all of the women in the study can talk to each other, and I might also send you a personal e-mail to discuss an issue separate from the rest of the group. Your identity would be known only to me...you'd be using a pseudonym on the bulletin board. Since this is a bulletin board and not a chat room, you can sign on and respond to the discussion at your leisure...there is no set time of the day that you would have to log on. All I'm asking is that all participants log on a minimum of twice a week, once to respond to a new question, and once to respond to someone else's response. Since you would be doing this in your free time, you can certainly sign on more often if you wish (that would be great!), but if time gets tight you can still participate at the twice-a-week level. I'm asking the participants to sign on for a semester's worth of discussion, although it could take less...when we've exhausted the topic, we're done. At the end of the study, I'd like to do an exit interview with each individual participant, either on the telephone or in person.

I hope that you'll be interested in participating...you input would be very useful. Please feel free to ask me any questions at all about the study, but also please get back to me soon so that I can know whether you are interested. Thanks so much for your time, and I hope to hear from you soon!

Sincerely,
Lynn Gieger

P.S. As I mentioned, I'm hoping to gather a relatively large group for this bulletin board discussion (10-12 participants, ideally). [ ] was kind enough to pass your name on to me, and I'd appreciate it if you could also pass on the names of any women that you think might be interested. (Even if you don't participate in the study, you could still possibly help me in this respect.) All I'm looking for is mathematically talented college women (sophomore or above) in a variety of majors. It certainly doesn't have to be a student at your university...a friend at another college or university would be a great contact! If you think of anyone, please pass along their name and e-mail address. Thanks so much for your help!

APPENDIX B

BIOGRAPHICAL QUESTIONNAIRE

- Name:
- Age:
- Race (optional):
- College mailing address and phone number:
- Home mailing address and phone number:
- E-mail address:
- Approximately how often do you check your e-mail?
- Approximately how often do you access the Web?
- Give your college major(s): (If you have changed your major at any time during college, list all previously intended majors, ending with you currently declared major.)
- Do you consider your currently declared major to be in a mathematical field?
- List all mathematics courses taken in high school and college, along with your letter grade for that course.
- List any mathematically related activities that you have participated in during high school or college outside of your classes (i.e. summer academic camps, math team).
- Please give your score on all of the following exams that apply to you:
  - SAT-M (from SAT I): __________
  - SAT II Math Achievement Test: ___________
  - Advanced Placement Exam, Calculus: ___________
- Have you ever been exempted from a high school or college mathematics course? If so, give the course name and the reason for the exemption.
- Is there any other information that you think I should know about your eligibility or interest in participating in this study?

APPENDIX C

OUTLINE OF WEB SITE ENTRIES FROM STRAND 1

Strand 1 [Forum: Main]

21. Instructor (Sun, Feb 13, 2000, 16:48)
    22. Nan Gartner (Sun, Feb 13, 2000, 20:56)
        24. Instructor (Sun, Feb 13, 2000, 23:18)
            25. Nan Gartner (Mon, Feb 14, 2000, 21:06)
                27. Instructor (Tue, Feb 15, 2000, 09:30)
                31. Esther Valentine (Sat, Feb 19, 2000, 01:15)
                    32. Nan Gartner (Sat, Feb 19, 2000, 16:52)
    23. Rachel Taylor (Sun, Feb 13, 2000, 22:50)
    26. Jane Yellow (Tue, Feb 15, 2000, 03:57)
    28. Maude Harold (Tue, Feb 15, 2000, 23:32)
        29. Nan Gartner (Thu, Feb 17, 2000, 01:12)
            36. Maude Harold (Tue, Feb 22, 2000, 14:23)
                43. Nan Gartner (Web, Feb 23, 2000, 18:56)
            39. Rachel Taylor (Tue, Feb 22, 2000, 14:32)
    30. Esther Valentine (Sat, Feb 19, 2000, 00:51)
    40. Emily Crane (Tue, Feb 22, 2000, 18:57)
    33. Instructor (Tue, Feb 22, 2000, 11:54)
        35. Maude Harold (Tue, Feb 22, 2000, 14:20)
        37. Rachel Taylor (Tue, Feb 22, 2000, 14:26)
        41. Nan Gartner (Wed, Feb 23, 2000, 18:44)
        45. Jane Yellow (Thu, Feb 24, 2000, 03:42)

APPENDIX D

TOPICS AND SAMPLE QUESTIONS FROM EACH STRAND

Strand	**Topic**	**Sample Questions**
1	Definition of mathematical talent and talent in general	At what point in your life did you begin to think of yourself as being mathematically talented? Was there any particular event or events that led you to that impression? Has your impression of your mathematical talent changed over time? What is the relationship between being good at something and enjoying it?
2	Perceived difficulty of major	On a scale of 1 to 10, with 10 being the most difficult, give a score of difficulty to your college major(s). How much did the difficulty of your major affect your choice? How difficult do you think other people find your major to be? Did the difficulty perceptions of others have anything to do with your choice of major?
3	Current enjoyment and long-term usefulness of major	Previous research indicates that there are two prevalent reasons for choosing a major in college…current enjoyment (the pleasure you gain from taking your classes, a general interest in the subject, etc.) and long-term usefulness (the relevance of your major to your career and future life goals). What was the role of these two elements (current enjoyment

		and long-term usefulness) in your choice of major? Which one was more important to your when making your choice? Where do you see yourself in 10 years?
4	Attributions for success and failure	Tell me about an academic situation where you were particularly successful and describe what you think led to your success. Work through the same process for a situation in which you were less successful. Do you attribute your successes and failures differently when working in a group?
5	Conclusions	Over the course of this discussion, many of you have pointed to enjoyment as being a factor in your decision of a major. In fact, for the majority of you, it would seem to be the central factor.. However, I'm interested in finding out exactly what it is that you enjoy about your area of study. Can you give specific examples? Are there also examples of things that you don't enjoy about it? Given the many options that all of your had in choosing a major (for you are all obviously highly talented, and not just in the area of mathematics), what made your final choice more enjoyable than others?

APPENDIX E

COMPREHENSIVE INTERVIEW PROTOCOL

<u>Expectation of Success:</u>

Beliefs about talent

What is your personal definition of mathematical talent? Do you think that you possess mathematical talent?
Are proofs a necessary part of mathematical talent? Do you like proofs? Why or why not? Is collaboration essential to a good proof?
What is the difference between arithmetic talent and mathematical talent? Is there a difference?
Do you think of your mathematical talent as being fixed throughout your life, or is it changing?
Have you ever doubted your mathematical abilities?
Can you be good at math AND good at something completely unrelated to math?
What is your definition of talent in general? How do interest and passion play into your definition? Can you have talent without interest and passion?

Task difficulty

Has something academic ever been too easy for you? (i.e., so easy it was boring and you didn't want to continue?) Have you ever had that experience in mathematics?
What about something being too difficult?
Do you find that you prefer classes/activities that are easy or difficult?
Does an academic discipline need to be difficult in order for you to take it seriously?
How much effort do your classes usually require of you? Would you classify that effort as a struggle or necessary diligence? Do your peers seem to require the same level of effort?
Do you enjoy the fact that your major is considered difficult by others? How does it make you feel if your major is considered easy by others?

Attributions for success and failure
How do you define success?
What motivates you to succeed? Grades? Praise? Excitement at understanding a difficult concept?
Is a desire to succeed enough generally to insure your success?
If something comes to you very easily, do you still consider yourself successful at it?
Have you ever said "Oh, I just got lucky" in a successful situation, even though you didn't mean it?
What do you see as the relationship between effort and ability?
How much do your professors have to do with your academic successes and failures?
Do you think that some disciplines typically have worse professors than others?
Do you get more satisfaction out of a group success or an individual success? Do you think that success is more likely in group setting versus working individually?
Do you have a tendency to blame yourself if a group isn't successful?

Value of the activity:

Aesthetic value
What are the enjoyment factors of mathematics (if any)? How do those differ from your major, if applicable?
Can someone enjoy doing proofs AND "tedious" computations?
Have you ever gotten "in the zone" while doing mathematics? What about when doing something else? What is the relationship between this "zone" and talent at an activity?
How important is academic variety to you?
Do you gain more fulfillment in your major from doing something "useful" or doing something abstract?

Long-term usefulness
What do you think are the external rewards of a mathematically oriented career? Does it have greater external rewards than other academic areas?
What do you think you can do with a undergrad major in pure mathematics?
Are short-term enjoyment and long-term usefulness mutually exclusive issues? What about long-term enjoyment? How confident are you that you will find a job that you enjoy?
Have you ever felt the pressure to choose a career that's more "prestigious," even if it isn't what you really wanted to do?
Do you feel like your career will give you kind of balance that you want in terms of your personal and professional life?
Do you feel pressure to "have it all"? What does that term mean to you?

What do you think is more important…personal fulfillment or professional fulfillment?
Do you think that you major will lead you to a career with some positive social impact?
Is this important to you?
Did you find it easy to pick one major over another?

Other influences:

Do you feel as if your college professors have added or detracted from the enjoyment of your math classes? What about classes in your major?
Do you find that mathematics classes are less supportive (i.e., colder, harsher) than other academic disciplines?
How much influence did professionals in your field have on your choice of major?
In terms of parental influence, who had more impact on your view of your adult life, your mother or your father? Do you find that you are emulating this person or going in an opposite direction?
Do you find that you have a gender peer group in your major? Does that matter to you?
Did your peers influence your choice of major?