Mathematics Education Research Journal 2005, Vol. 17, No. 3, 22–44

The Calculus of Differences: Effects of a Psychosocial, Cultural, and Pedagogical Intervention in an All Women's University Calculus Class

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The purpose of this study was to investigate the ways in which a multi-layered women's calculus course influenced the participants' learning of mathematics. This study, conducted in a state university in the Midwestern region of the United States, revealed not only that women in this particular section of calculus were likely to select careers that involved mathematics, but that the focus on peer support, psychosocial issues such as self-confidence, and pedagogy helped the young women overcome gender barriers, as well as barriers of class, poverty, and race. In this article we provide some of the relevant quantitative statistics and relate the stories of two particular women through excerpts from interviews, student artefacts, and participant observation data. We selected these young women because they faced multiple barriers to success in Calculus I and might not have completed the course or taken additional mathematics courses without the support structures that were fundamental to the course.

For the past three decades, considerable amounts of research and attention have been directed toward the differences between men's and women's participation and performance in mathematics, as well as their choices of careers that require more than basic mathematics (Goodell & Parker, 2001; Leder, 1992). The number of women *choosing* to concentrate in fields that require mathematics has increased significantly since 1970. Nevertheless, the number of women *completing* undergraduate degrees in such fields remains low (Chacon & Soto-Johnson, 2003), and males enrol in higher-level mathematics classes more often than females (Barnes, 2004; Forgasz, Leder, & Thomas, 2003).

In Australia, England, the United States, and throughout other English speaking countries, the numbers of women and men in science and mathematics-related professions differ greatly (Leder & Forgasz, 1998; Mendick, 2003). Ultimately, women's lack of enrolment in advanced mathematics classes prevents them from pursuing degrees in other fields such as physical sciences, computer sciences, or engineering (Atweh, Bleicher, & Cooper, 1998). Because many mathematics classes are prerequisites for technology classes, enrolment in technology programs is also affected. In countries such as the United States and Australia, women comprise approximately half of the workforce, yet they represent only about 15% of the scientists. Even smaller percentages of women go into engineering, physics, and computer science.

Females' lower participation in mathematics at the university contributes to the overall concern of "[t]he professional communities of scientists and mathematicians … about the declining numbers of graduates and postgraduates in the physical sciences and mathematics" (Forgasz et al., 2003, p. 242). Forgasz et al., along with others (e.g., Jones, 1998; Thomas, 2000), have suggested there will be a critical shortage of qualified mathematics and science teachers if participation in mathematics does not increase. The problem may be perpetuated when women are confronted with few role models of women in mathematics or science.

Theoretical Framework

Previous Research on Gender and Mathematics

Becker (2003) stated that research on gender and mathematics has matured and evolved from deficit models in which women's performance in mathematics was negatively compared to men's. In about three-fourths of the 48 countries participating in the TIMMS (Third International Mathematics and Science Study), no gender differences were found in achievement. In a few counties, such as Australia, girls' total scores in school mathematics were found to be higher than boys' (Leder & Forgasz, 1998).

Much of the research on gender and mathematics has shown that psychosocial factors contribute to gender differences in participation in mathematics and science classes (Davenport, 1994). Significant relevant factors include self-confidence, self-concept, self-efficacy, prior experience, and the perceived usefulness of the field of study. While self-efficacy and self-concept are closely related, they are not identical. Asking oneself, "Am I good in maths," is related to self-concept while asking oneself, "Can I solve this problem," is related to self-efficacy. Self-efficacy—valuing one's own capability to organise and execute courses of action required to attain designated performances—strongly influences the choices people make (Bandura, 1986). Self-efficacy has been found to be especially pertinent to women's learning of mathematics; even highly talented females report less self-efficacy than males when completing mathematical tasks (Seegers & Boekaerts, 1996).

Seegers and Boekaerts (1996) also confirmed that self-confidence is positively related to mathematics achievement. In particular, their findings demonstrated that academic self-confidence is the cumulative outcome of long-term interactions between the cognitive and affective aspects of learning. In samples of students from primary school through university, academic self-confidence is significantly correlated with mathematics achievement and is also seen as critical for motivation and persistence in mathematics. There are noticeable gender-related differences in attributions of achievement. Most female students are less self-confident in their own abilities than males and are more likely to attribute failure to low ability rather than to other factors (Fennema & Hart, 1994).

Psychosocial factors combine with cultural factors to affect women's attitudes toward mathematics (Davenport, 1994). Some women dislike the competitiveness of mathematics classes, to the extent that they may avoid interaction with teachers during sessions that involve competition. Women also feel alienated by the manner in which the subject is conveyed and express anger when faced with stereotypes of females as being less serious than male students (Fennema & Hart, 1994). But most of all, numerous women describe a growing frustration with the seeming lack of connection between mathematics and the world surrounding them (Stage & Maple, 1996).

Consequently, researchers have found that women are particularly sensitive to support features that make their educational environments appear less hostile (Stage & Maple, 1996). Research also suggests that peers play important roles in women's experiences in courses of study that require higher mathematics. Having friends who share an interest in mathematics is important for females, because friends provide a sense of solidarity, support, and added visibility (Baker & Leary, 1995). Beal (1994) found that if women cannot find peer support for taking mathematics, they often change their major courses of study.

The interconnectedness of various factors determining women's success in mathematics is also evident when research on mentoring is examined. When women do pursue fields that require mathematics, they often do so because of successful early childhood experiences with parents or interested teachers (Jacobs, Finken, Griffin, & Wright, 1998). Most can name a particular person or persons responsible for their interest and success in an undergraduate degree in mathematics. Without such mentoring, they would not have made it in mathematics. Similarly, many women who succeed in undergraduate mathematics classes credit support networks and study groups created by faculty and administrators (Stage & Maple, 1996). Women from backgrounds without access to such mentors may be disadvantaged.

Women also bring multiple backgrounds into the mathematics classroom, some of which create obstacles to their success (Burton, 2003). Collins (1991) argued that the multiple barriers women face are a result of a "matrix of domination" in society in which certain individuals have historically been oppressed. Collins argued that oppressions are not "additive" but "interlocking" and that acknowledging this fact allows us to understand society better. "The significance of seeing race, class, and gender as interlocking systems of oppression is that such an approach fosters a paradigmatic shift of thinking inclusively about other oppressions" (Collins, 1996, p. 225). Women's work in the classroom is not easily understood without considering the other barriers they face or the support they receive (Burton, 2003; Mendick, 2004).

Pedagogical Interventions for Women in Learning Mathematics

The previous discussion helps to explain why many women drop out of mathematics courses and indicates that women do best in settings which provide positive mentoring and support as well as in environments that de-emphasise negative stereotypes concerning women's participation in mathematics (Jacobs & Becker, 1997). Many females may thrive in classes in which the curriculum and pedagogy are congruent with women's ways of knowing, and in which women are visible as capable and powerful learners. Those who develop the ability to learn independently of instructors might also contribute to the elimination of gender differences in mathematics (Fennema & Leder, 1990).

The State University of New York at Potsdam has implemented a successful mathematics program along these lines (Rogers, 1990). The program was recognised by the Mathematics Association of America because of the large number of undergraduates specialising in mathematics that it attracted (a majority of whom were women) and the variety and quality of mathematics classes it offered. A team of researchers evaluating the program found a teaching staff that was especially sensitive to issues of gender and mathematics and had taken special care to provide support for female students. The most interesting finding, however, pertained to the actual teaching of mathematics in the classes. The researchers were surprised to find a staff of 14 males and one female instructor; clearly, the instructor's gender was less important than her or his concern about students in general (Hart, 1992). Teaching techniques were at the core of the success of the Potsdam mathematics program (Rogers, 1990). Teachers worked with students so that they constructed the mathematics together and students learned that they were able to recreate mathematical theories for themselves.

Other researchers and educators have created different interventions to encourage women in mathematics. The calculus class for adult women developed by Barnes and Coupland (1990) focussed on increasing motivation, building confidence, developing teaching methods based on research on women's learning styles, and exploring problems relevant to women's interests. Single-sex schooling, too, has been promoted to encourage women's participation (Mael, 1998). However, Forgasz (1995) found that neither single-sex nor mixed mathematics settings was more effective in enhancing positive feelings towards the learning of mathematics. Nevertheless, Forgasz recommended further qualitative studies to examine "the more subtle classroom processes that may be contributing elements" (p. 174) to gender differences in single-sex classrooms.

Research on Women's Ways of Knowing

Becker (2003) maintained that "[t]raditional ways of teaching mathematics – stressing certainty, a single correct answer, deduction, logic, argumentation, algorithms, structure, and formality – may be particularly incompatible with the ways in which many females learn" (p. 470). Support for this claim comes from Belenky, Clinchy, Goldberger, and Tarule (1986) who conducted research with 135 women and found that the traditional methods for teaching mathematics led some females to avoid mathematics and related careers.

Belenky et al. (1986) theorised women's cognition or ways of knowing through stages. Their procedural knowing stage distinguishes between separate knowing and connected knowing. For the separate knower, knowledge is predominant; for the connected knower, understanding is predominant. At the heart of separate knowing is critical thinking and the construction of arguments in which feelings and personal beliefs are excluded. Belenky et al. claimed that separate knowing is essentially an adversarial form because students are challenged to prove the validity of an idea. Jacobs and Becker (1997) elaborated on this idea and stated that traditional mathematics classrooms are "more consistent with separate knowing" (p. 108). They found in their research that many women disliked being in an argumentative atmosphere and would patiently wait until it ended before they participated. In contrast, connected knowers learn through making connections. These learners want to form a relationship between themselves, their peers, and ideas. Becker (1996) said that "[c]onnected knowers focus on the context and other people's knowledge" (p. 20). The connected knower finds it helpful to maintain a group connection where she can learn to create her own system of knowing and develop her own authorities.

Purpose of the Intervention

We set out to devise a single-sex calculus class that was designed around connected learning. We were determined to provide support structures to enhance participants' confidence and self-esteem. Because the current gap between men's and women's participation in higher mathematics develops from settings in which separate knowing is predominant, we decided to promote connected knowing in our intervention. Connected knowing seemed most appropriate to the kind of work required in advanced mathematics. We hoped that our intervention would increase women's retention and participation in higher levels of mathematics classes and diminish the effects of social and cultural barriers.

To assess our intervention, we performed both quantitative and qualitative data collection and analyses. We frame the discussion of our findings by presenting quantitative data about students' retention in mathematics during and after the intervention. However, the most complete picture of the effects of the students' participation in the calculus class came from the qualitative analysis. The qualitative analysis provided insights into the personal experiences that contributed to the women's success in calculus and forms the main focus of this article. After the discussion of quantitative findings, we present the stories of two women and the ways the experience of being in the women's calculus class helped them overcome barriers to success in mathematics.

Structure of the Focussed Interest Group

The calculus intervention project at a mid-sized Midwestern state university in the United States was designed to create a community of students engaged in collaborative problem-solving and other activities (both in class and in a separate support group). The women students in the intervention section of calculus registered for six credit points in a Focussed Interest Group (FIG). The Mathematics Department provided a four-credit calculus class and a one-credit problem-solving enrichment session. Students also registered for an associated section of UNIV 101, a one-credit orientation class specially planned to improve their study of mathematics, provide information about the importance of mathematics to their futures (and careers in mathematics), and offer role models and mentoring. During the first of the two years of this study, the UNIV 101 class met in the university's women's centre. During the second year, the women met in the conference room of the Women's Studies Program. The Mathematics Department and Women's Studies program staff provided support for the UNIV 101 class.

The FIG for women in mathematics was publicised extensively before and during registration. As with regular Calculus I classes, students were required to pass a mathematics placement test to qualify for admission into the FIG. Students who did not pass the mathematics placement test at this level were required to take other mathematics classes (e.g., university algebra, pre-calculus, and trigonometry) before taking calculus. In addition to listing the FIG in the schedule book, flyers about the program were made available at orientations and in appropriate advising offices.

The FIG was open to all students but, as anticipated, the emphasis on women's issues discouraged males from enrolling. The grant staff was primarily female. However, given the results of the Potsdam study, both males and females had opportunities to work with the women. In light of the limited number of women who teach calculus at the university, a male professor, one of the Mathematics Department's most talented calculus professors, was asked to teach the four credit point calculus class that was part of the intervention. He showed much interest in the project and contributed greatly to it. The involvement of mathematics education personnel further ensured that the project's goals were met.

We provided the Calculus I professor with existing research in developing appropriate teaching strategies for the class (Barnes, 1995; Barnes & Coupland, 1990; Rogers, 1990; Willis, 1998). He drew upon this research to focus the class on establishing a mathematically-based challenging community of learners. The curriculum humanised mathematics; mathematical concepts were placed in context through problems that connected to students' interests, experiences, and relationships. Such contexts included world population growth, rates of absorption of drugs into the bloodstream, concentrations of pollutants in lakes and rivers, and inflation rates for car air bags. Using an inquiry approach, the professor guided students through a process of creating mathematical concepts for themselves so that mathematics made sense to them. The learning environment was less competitive and more collaborative than in traditional calculus classes. The professor used small groups in order for students to communicate with each other and to clarify or justify their thinking about mathematics. Students talked about how they solved problems and received feedback from other students as well as the teacher. They also wrote narratives describing how and why they used certain problem-solving strategies. These narratives included explanations and mathematical computations. Alternative forms of assessment such as journals and self-critiques were used as well.

These modifications were possible because of the way the Mathematics Department structured its calculus classes. Calculus I is a departmentally coordinated class; however, instructors may choose their own materials. Individual instructors assign final marks to their students and use their own discretion when grading quizzes or homework. The students must also take four one-hour examinations prepared by their individual instructors. In the end, however, each student must take the same departmental final examination. This common examination was an essential part of our strategy for evaluating how the work of the women in the intervention compared to that of the male and female students in the other sections.

In the weekly problem-solving session, students in the intervention continued to work in collaborative groups to solve more extended calculus problems using more in-depth investigations. A doctoral student in mathematics taught this class; she also helped the students create study groups. The same doctoral student taught UNIV 101, in which she focussed on issues particularly pertinent to women and fostered a support group among the women. Students learned how to manage their time, how to read a mathematics book, and how to organise their study. Notable women, such as a female astronaut, spoke on campus, acting as role models for women who studied mathematics. To learn more about women's achievements in mathematics, students also viewed videos on famous women in the field. Additional enrichment occurred when the women in the FIG read the Tony award-winning play, *Proof*, and later attended a performance of this play about a woman seeking recognition for her work in mathematics. They also went on field trips to The Museum of Science and Industry and The Aquarium. The instructor for the orientation class acted as a mentor for the women, along with the calculus professor, a professor of mathematics education, and the director of the Women's Studies program. All of the mentors were available if students wanted to talk about their concerns. In addition to the problem-solving enrichment sessions, the students convened for voluntary study meetings five times during the semester. The doctoral student led these sessions.

As in most universities in the United States, Calculus I is a one-semester introductory class consisting mostly of differential calculus. Students who need more mathematics for their major courses of study and choose to take more mathematics normally take Calculus II in the semester after they take Calculus I. During both years of the FIG, the students requested to stay together as a group for Calculus II. This idea had not been part of the original plan, but the Mathematics Department made it possible for them to do so, and assigned the same professor to teach them Calculus II. The Calculus II classes also included other students, both male and female. In the second semester, there were no additional credit points for workshops, but students could meet voluntarily every week with the doctoral student for enrichment. Most of the registered students came to these voluntary problem-solving meetings. The doctoral student also conducted study sessions five times during the semester. The grant staff continued to mentor the students.

Methodology

The Predominant Research Method: Case Study

Our predominant research methodology was case study (Stake, 1995) because we wanted to capture the complexity, particularity, and detail of the interactions within the FIG and to explore whether or how the FIG benefited the students enrolled. In addition, case studies provided the means for obtaining a naturalistic, descriptive, holistic, and ethnographic view of the students' experiences (Stake, 1995). Qualitative research seemed better suited to answer the research questions and to learn in what ways students were influenced by participating in a multi-faceted women's calculus class, and in what ways these influences affected their mathematics learning or willingness to take additional mathematics classes.

Participants

The participants were 32 women who passed the mathematics placement test qualifying them to take Calculus I. All of the women were between the ages of 18 and 20. Some had declared various courses of study, such as mathematics education, physics, marketing, while others remained undecided. They were from diverse backgrounds; many were from families in which they were the first to attend university. One woman was of both African-American and Hispanic descent; one was Asian-American; one was Hispanic; one was Middle Eastern; and the other women were Caucasian.

Quantitative Data Collection and Analysis

We compared the retention in higher-level mathematics classes between the women in the FIG and three other groups of students: all other students who took Calculus I, all other new first-year students who took Calculus I, and new female first-year students who took Calculus I (besides those in the FIG). New first-year students are those who have no university-credit points when entering in the fall semester. All other students are students who may have been repeating Calculus I and students who are not classified as new first year (i.e., second year). Combining the data from school year 2001 and

2002, we computed three chi-square statistics to compare the percentages of students who took Calculus II in the next semester. We combined the data for the two years because the number of students in the FIG in each year was small, 13 for the first year and 19 for the second year (a total of 32 students). We also calculated a chi-square statistic for each group of students to test for possible significant differences in the percentages of students scoring above or below a C in Calculus I.

Qualitative Data Collection and analysis

Based on the findings of prior research, in order to enhance the validity of the research findings, we collected qualitative data in three different ways throughout the two years: through interviews, participant observation, and artefact collection (Lincoln & Guba, 1985). We audiotaped and later transcribed three formal interviews with each student; one at the beginning of Calculus I, one at the end of Calculus I, and one during Calculus II. Each interview lasted about one hour. After each interview, the researcher documented her observations in a journal, where she reflected on future questions. In addition, we conducted informal interviews with students during study sessions, enrichment time, and office hours. We also conducted formal interviews of both the calculus professor and the doctoral student who led the problem-solving enrichment and the orientation classes. For four semesters, one of the researchers observed almost every Calculus I and II class in order to examine and understand the students' interactions with the professor and with each other. In addition, in order to evaluate the learning environment, at least one of the researchers observed the UNIV 101 orientation class every week. The researchers kept extensive field notes from each observation. We collected documents including copies of student quizzes, tests, worksheets, letters, and notes to instructors and mentors. Finally, we collected student journal writings in which we asked for feedback regarding different aspects of the intervention and suggestions for modifications.

We systematically and rigorously organised, analysed, classified, and consolidated the data using the Developmental Research Cycle (Spradley, 1980) to determine patterns and cultural themes. This type of data analysis enabled us to make the transition from posing general questions to asking more specific ones resulting from the data. We transcribed the audiotapes in an ongoing manner to allow for preliminary analysis which, in turn, alerted us to the need for additional data. The researchers also examined the transcripts multiple times for evidence of recurrent themes. After reading the transcripts independently and making tentative conjectures, we sometimes listened to the audiotapes again for more analysis. This process at times led to new or revised conjectures.

Quantitative Results

Continuation in Mathematics Classes, Achievement, and Retention in Degree Programs Requiring More Mathematics

We conducted chi-square (χ^2) analyses to determine if there were significant differences in the proportions of FIG and non-FIG students who continued on to Calculus II among three separate groups of students: all other students, other new first year students, and other new female first year students. The χ^2 results are shown in Table 1.

Table 1
Proportions of FIG and non-FIG students (all, new first year, and new female first year) continuing onto Calculus II and χ^2 results

		Calculus II		
		Enrolled	Not enrolled	χ^2, p-level
All students	FIG all	23 (72%)	9 (28%)	
	Non-FIG all	269 (42%)	366 (58%)	10.78, p<.05
New first year students	FIG new	20 (71%)	8 (29%)	
	Non-FIG new	137 (50%)	138 (50%)	4.75, p<.05
New female first year students	FIG new female	20 (71%)	8 (29%)	
	Non-FIG new female	26 (43%)	35 (57%)	6.38, p<.05

As can be seen in Table 1, there were statistically significant differences in the proportions of women in the FIG groups compared to the other groups who continued on to Calculus II. In each case the proportion of FIG women moving on to Calculus II was higher.

Interestingly, 43% of the new first-year women who continued to Calculus II were women who had been enrolled in the FIG even though they were only 31% of the new female first-year students originally taking Calculus I.

We also conducted chi-square analyses (χ^2) to determine if there were significant differences in the proportions of FIG and non-FIG students who were enrolled in Calculus I in 2001 and 2002 with marks above C and below C among three separate groups of students: all other students, other new first year students, and other new female first year students. The χ^2 results are shown in Table 2.

Table 2
Proportions of FIG and non-FIG students (all, new first year, and new female first year) enrolled in Calculus I with marks above and below C, and χ^2 results

		Marks		
		A, B, C	D, F, W.I.O	χ^2, p-level
All students	FIG all	29 (91%)	3 (9%)	
	Non-FIG all	389 (61%)	246 (39%)	11.23, p<.05
New first year students	FIG new	25 (89%)	3 (11%)	
	Non-FIG new	204 (74%)	71 (26%)	ns
New female first year students	FIG new female	25 (89%)	3 (11%)	
	Non-FIG new female	50 (84%)	11 (16%)	ns

The only statistically significant difference in the proportions of students with marks above and below C was found among the women in the FIG and all other students who took Calculus I, with a higher proportion of FIG women achieving higher marks. The proportion of FIG women among the new first year students with marks higher than C (89%) was greater than all new first year students (74%) but was not significantly different due to small numbers.

At this point, it is important to mention that the professor who taught the intervention class believed that he had taught the students in more depth and expected more rigor from them in their regular hourly examinations than in his past Calculus I classes. He claimed that he taught the group as if they were in the honours section of calculus. The students also performed comparably to students in other sections on the common department final examination. The final examination did not include the conceptual types of problems in context that the professor predominantly had used in their calculus class and hourly examinations, yet the students' learning carried over. Another important point is that even though 84% of other (non-FIG) new female first-year students scored marks of C or better, only 43% of these students took Calculus II in their second semester.

One of the issues for women taking mathematics is that even those who come to university interested in courses of study that require higher mathematics often change their degree areas to ones that do not require mathematics (Beal, 1994). We found this to be true when we examined the historical statistics in our department; however, we found it difficult to obtain specific numbers. Examining the number of students in the FIG who stayed in degree programs or changed their degree programs to ones requiring more mathematics than Calculus I revealed positive trends. The numbers of FIG students and whether they changed or remained in various programs are shown in Table 3.

Table 3
FIG students' major courses of study in third year

Remained in fields requiring more than Calculus I	10
Changed to fields requiring more than Calculus I	9
Remained in fields not requiring more than Calculus I	10
Changed to fields not requiring more than Calculus I	3

As can be seen from Table 3, by their third year 19 students of the 32 students were enrolled in majors requiring more than Calculus I. Originally, 13 students had been enrolled in programs that required more mathematics than Calculus I. We were able to retain ten of the 13 students (five retained majors that required mathematics beyond Calculus II). Also, nine of the students changed their courses of study to ones that required more mathematics than Calculus I (eight changed to fields that required classes beyond Calculus II).

Qualitative Findings: The Experiences of Two Women in the FIG

The findings discussed in the following section are presented as two cases. We selected these young women because they faced multiple barriers to success in Calculus I and might not have completed the class or taken additional mathematics classes without the support structures of the FIG.

Carmen

Carmen enrolled in university as a mathematics education student. She had good study skills, was self-motivated, and liked mathematics. She was the only female in a special class that focussed on mathematics in architecture. Carmen viewed the men's responses to her presence as stereotypical. Carmen said, "I was better than all the guys. And they got mad because they were like, this is a guy class." Carmen did not come from a school where females were consistently encouraged to take mathematics. She described how one of her male mathematics teachers used negative stereotypes to motivate girls:

> He would always say things like, 'Girls can't succeed, women can't do math.' Then at the end of the year he said, 'I hope you realise that I don't despise girls, but that was my way of encouraging you, so that you could rub it in my face that you could do it.'

When asked if she thought his method was helpful, Carmen replied:

> I always thought about what my mom said, 'Don't let anyone tell you that you can't do something.' So I worked twice as hard just to prove to him that I was as good as any guy in the class. [However,] only three girls passed the class. The rest of the girls did not. I had an A in the class.

Carmen also talked about a female teacher who told her not to show her ability in mathematics because it would embarrass the boys.

Carmen's family was not affluent and she was from a rough part of the city. Her family was multi-racial, combining African-American and Latino cultures. She had always worked hard on her own to succeed. Few of her secondary school friends had taken university preparatory courses. As a result, Jill, the doctoral student teaching the orientation class and problem-solving enrichment, had difficulty persuading Carmen to work with peers during the problem-solving hour. Jill remembered:

> At the time, I thought that she was feeling very isolated because she felt everyone else in the class was white. In UNIV 101 she talked about her [secondary school] and the gangs, and it seemed so different. The other women said, 'Wow, where did you go to school?'… In [secondary school] she had studied on her own and that was it. Carmen did not want to work with anyone else.

However, Carmen did receive support from her mother. Her mother worked two jobs to help Carmen stay in university:

> She's always encouraged me to do whatever I wanted to do … She knows that I always wanted to do this … She doesn't have the money for me to go here, so she had to take out a bunch of loans. And I'm going to pay her back—all of it.

At one point during the research, we thought Carmen would have to stop living at the university and commute one and a half hours each way to school. Ultimately, she was successful in obtaining additional financial aid so that she could continue to live on campus.

Regardless of her study skills and mathematics background, she struggled in Calculus I and received a C. This mark was very unsettling to her, and so, by the time she came back from semester break to begin Calculus II, she had decided to change her approach. The first day of class she walked in, sat in the front row, and positioned herself beside Martha, who was perceived as one of the best Calculus I students from the previous semester. Carmen said, "I want to work with you." Martha gave Carmen a look of encouragement and seemed eager to work with Carmen. Jill, who was observing the class, said that Carmen spoke almost as much during that 50-minute class session as she had the entire previous semester. She did not speak to the class in general, or answer any questions, but discussed with Martha the problems which Richard, the professor, was working during the class period. As the semester progressed, Carmen became increasingly outspoken and interested in being a part of the group. She also began to study with others. She worked hard and decided that she needed to solve every problem in the book. She thought this would increase her chances of being able to work most problems that Richard might suggest during class or ask on a test. She proudly asserted to Richard, "It [won't] matter what problem you assign, I've done them all." When Richard gave back the first test, Carmen could not contain her enthusiasm. She was delighted with her result, which was an A. She jumped up from her seat and shouted, "Look what [mark] I got!" She had received the highest mark on the test. Due to her determination to succeed in Calculus II, she earned an A for the class.

During the Calculus II semester, she developed a close relationship with two classmates, Maria and Lainey. One Monday night after a study session, they worked problems together and then later went out for a snack. From then on, they became very good friends. Carmen often ate with Lainey in Lainey's residence hall cafeteria. Maria, who commuted, often rested in Carmen's room. Outside of class all three studied together, and they came together to every Monday night study session. All three remain close. When Carmen, who did not have a vehicle, attended her first clinical for her professional teaching courses, Maria and Lainey took turns driving her.

At the end of her first year, when we interviewed Carmen about her change in attitude, she said:

> They [the FIG students] are kind of like my friends back at home. We talk about our lives. When I first came here, I didn't want to make friends. Well, I wanted to make some friends, but not like friends here to replace my friends at home. Then I was like, I don't have to replace them, I can have friends here and still have friends at home … I was going home [between semesters]. I realised I do have more in common with the girls here than I do at home. I should start talking to them more. So like the first day back, we all just started talking.

Carmen's sense of loyalty to her friends at home reflected her understanding of the differences in the cultures of her local neighbourhood and the university. After her first semester, she was able to see that she would not be disloyal to her old friends if she connected with other university students as well. She had talked about her experiences with her mother and felt that she was better equipped to accept that school as well as home could help define her identity and friends:

> When I explained it to [Mom], I said, 'Well, Mom, I have so much in common with these people.' She goes, 'Really—how or what?' We have problems in our family, and we all have sisters and brothers. Something we can't stand. We argue about cars, whether we should have a car or not … If you can talk to them about your life, then that makes it easier to ask them for help. Like with a family problem or a math problem.

Jill said about Carmen:

> Second semester she realised how much the [other women] could help her with the mathematics. During Calculus II she was one of the students who came regularly to Monday night sessions, and she would talk about us, refer to "the girls," that sort of thing, things she hadn't done first semester. She said, 'What are we taking in the fall? Calc III?'

Carmen was supported by the group, but she also contributed to the group. What she contributed most was a diverse background: coming from a poor urban secondary school; being African-American and Hispanic; and having different life experiences. She challenged herself and the other students to question their stereotypes of who could succeed in mathematics. She continues in her chosen field of mathematics education and is taking other mathematics classes.

Maria

Maria, too, was a student who had done well in secondary school mathematics and faced multiple difficulties in achieving success at the university. Unlike Carmen, she was from a small rural community. Her parents were protective and strict about her behaviour. Her father was a minister in a small church. Maria taught Sunday school and Wednesday night Bible study. She held two jobs—one as a waitress in a restaurant, and one as a salesperson at a women's clothing store. She drove almost an hour from home to the second job. She also commuted from home to the university. Maria took out educational loans to help pay her university expenses. Despite her parents' lack of financial support, Maria felt that they encouraged her and supported her decision to attend university even though they had been surprised by the decision. Maria understood that she had to be financially responsible for her tertiary education since it was her decision to attend university:

> They know that I'm paying for school on my own. They want to help, but they just can't. They understand that like it's my decision [to go to university] … They understand how hard it is, and how much time I have to put into it. They also understand how much I have to work, you know, two jobs during school and stuff like that. They are always there for me. So, I'm very grateful that they are, and, you know, even though they can't pay for school, they still give me a place to live and food, and take me out to dinner.

In spite of Maria's repeated emphasis that her parents supported her, we occasionally felt that her parents' encouragement was mixed. According to Maria, her parents, and especially her father, often made remarks to the effect that she was only attending university for future financial benefits, "Oh, well, if you marry someone rich then you don't have to worry about getting a job or getting a university degree." During an interview, Maria talked about how her parents reacted upon hearing that she intended to enrol in the university for her second year. According to Maria, her father sounded surprised. She did not know whether her father had thought she would transfer, drop out of school, or find another alternative.

Maria had enrolled as an undecided student (without having chosen a course of study) and took the calculus class because she qualified for it on the university's mathematics placement test. It seemed a logical class for her; she had liked mathematics in secondary school, and her teachers and guidance counsellors had suggested she keep taking mathematics: "They tell you, you know, math is what you need to take or, you know, you should take this." She also discussed why she took the calculus class, "I knew no matter what course of study I would have chosen, I was going to take a math class … every semester, because I enjoy doing the math."

Maria participated in the class from the beginning. She was very helpful and supportive of her peers, too. Instead of isolating herself at the beginning as Carmen did, during the weekly problem-solving enrichment hour, Maria explained her solutions and worked with others. She never dominated the problem-solving, but always made sure that everyone in her group had the opportunity to explain her thinking. Jill observed:

> In the first semester [Maria was often one of] the two people that if there were informal groups, and Lainey was getting left out particularly, I could ask, 'Why don't you check with Lainey?' Maria would sort of fall into her teacher mode. 'Well, what did you get, Lainey? What did you do?' One day during calculus class she was explaining how she worked a problem, and another student said to her, 'You should be a teacher. You are so good at telling why you solved a problem, and you are so patient.'

Maria's eyes lit up. Directly after class that day she walked down to the mathematics department to change her undergraduate focus from undecided to mathematics education. Her spirits lifted after she made the change. She described how in the early part of the first semester, she was always "stressed and frazzled" and now realised that it was "because I had this idea that I had to pick a course of study" and a career. Maria said, "I finally [feel] like I am doing something about my future. It has been weighing me down and everyone keeps asking me what I am earning my degree in." She was pleased and talked about how she went back home during the break between semesters to tell her secondary school pre-calculus teacher that her undergraduate program was in mathematics education. He smiled and said, "Well, I could see you doing that."

Maria was the student in the FIG who was most eager to encourage future students to enrol. She was very interested in attending open houses for senior secondary school students during the second semester. She made sure the secondary school students learned about the FIG. She was also one of the students who offered to remain involved with the FIG in the upcoming year by "helping out in any way or coming to talk to students." Jill believed that Maria also played a major role in persuading Carmen to come out of her shell. If Carmen talked or asked a question in class during the first semester, Maria was usually the person to whom she turned.

Ironically, Maria herself struggled with calculus:

> I really don't think I was successful in the beginning because I had ended [with] pre-calc in [secondary school]. Limits were the first thing we started with, and I didn't even know what a limit was. I felt like I was behind everybody, you know, like there were some people that understood it because they had taken calc [in secondary school] … Usually I can grasp things quickly but [limits] took a long time. I mean the algebra part of the limits I could get, but just understanding it's going

> to infinity, or it's going to zero. I would say towards the end and in the middle I became more successful.

She had a strong need to understand concepts fully and would not be satisfied until she had done so. Simply knowing how to solve the problems was not enough for her. Jill said that Maria probably would have given up if she had not had extra support from her peers, Richard, and Jill. It was important to all that she receive support because everyone knew how much she wanted a university degree, and it was unclear how much support she was getting elsewhere. According to Jill:

> I think she would have probably toughed it [the mathematics] out for the first semester, but I think she would have given up at some point, because she was very frustrated a few times after tests, frustrated that she knew something that she couldn't get across … It was very important for her to realise that she wasn't the only person. She would say, 'I'm not the only person having problems with this.'

Throughout the first semester, her mark was between a high C and a low B. She did not do well on the final, and therefore, received a C for the class.

Even though she struggled, mathematics education remained her field of study. Jill said, "She really enjoys it [the mathematics]" and indeed, Maria was memorable in the way she persisted even when it took her time to grasp concepts. The support structure built into the class strengthened her resolve:

> Like, just, you know, the work and the one-on-one attention. That really helped. I don't think I would have had as much attention if I was in a different calc class. I don't know if I would have still changed [my course of study] to be math.

Role models were another feature of the intervention important to Maria's continuation in mathematics. Maria talked about how Richard and Jill were role models for her as teachers:

> Richard has been a big influence on like everything that I do in math, like the decision for changing my [course of study]. Once I saw how Richard got into it and how focussed he was on his teaching, I thought maybe I could do something along those lines. He's not so much interested in your overall mark. His main concern is that you're getting the concept of what he's teaching. Personally, he made me feel like he really cared about my well-being and progress. Well, [Jill has] been a big influence on that, too … [She] made me believe in my abilities.

Richard felt she had made a good career choice and had the "talent to be an exceptionally good teacher."

Maria benefited from the FIG in other ways besides learning mathematics. Jill explained:

> The FIG was a great way for her to make friends on campus. Because she commuted, if she hadn't been in the FIG, that would have been much more difficult for her to do—to make close friends and meet people. She and

> Lucy became very close, and that was a big help for her. She had people she could ask, other students she could ask about different things.

Maria concurred:

> I don't think I would have made as great of [sic] friends [if I had not been in the FIG]. I really don't think I would have connected, like, you know, [come] to know everybody in that personal level, if we hadn't had that bonding time.

Maria is still in the mathematics education degree program and continues to take mathematics classes. Maria worked very hard in Calculus II and received a B. Like Carmen, Maria came from a family in which individuals generally did not attend university. Whereas Carmen received support from her mother, Maria relied on secondary school and university instructors as role models. The close interactions between students and staff in the FIG were of prime importance to her.

Discussion of Findings and Mathematics Learning

Both women's attitudes and marks improved as they proceeded through the calculus classes, and both selected careers that would enable them to use mathematics. The support structures built into the project were not designed to simplify the calculus or to treat women as victims. Instead, they were planned around research about the ways many women learn and were intended to improve women's sense of empowerment through their success in solving problems that were at least as rigorous as those faced by students in other classes. Jill and Richard set high expectations and challenged students in a friendly learning environment, making it clear that they were available to help. Interviews with the students indicate that this framework was beneficial.

The framework was particularly successful in retaining the kinds of women who, though prepared for higher-level university mathematics, often struggle and drop out of mathematics-related courses of study. A statistically higher number of the FIG women went on to enrol in Calculus II in comparison to all groups of students who took Calculus I at the same time. Unfortunately, this finding also underscores the fact that other new female first-year students (57%) did not move on to take Calculus II even though 84% of them achieved a mark of C or above for the class. These results coincide with those of Forgasz et al. (2003) who found that even women who do well in mathematics do not continue to enrol in higher-level mathematics courses. More specifically, both women discussed in this article had been good senior secondary school mathematics achievers and qualified to take calculus at our university. Each of them, however, had problems succeeding in the class. They needed support more than most of the other women in the FIG in order to do well and continue taking mathematics. While Carmen ended up receiving a C in Calculus I without much help, Maria would probably have received marks lower than her Cs without help from Richard, Jill, and other students.

The support they received in the first semester also encouraged the women to continue to take calculus in the second semester. Both succeeded in earning higher marks in Calculus II than in Calculus I. Without individual mentoring, these women might not have made it through the mathematics classes they needed for their degrees. Our findings thus support research by Stage and Maple (1996) which indicated that unless women receive specific encouragement they avoid mathematics and science-related careers. Not only did these women receive necessary assistance, but they were able to reciprocate by helping others. As in the research of Baker and Leary (1995), peers played an important role in the women's experiences with higher mathematics. The women developed friends within the FIG who shared their interest in the mathematics. These friends provided a sense of solidarity and support.

All of the women in the FIG occasionally experienced low self-confidence and needed encouragement from Jill and other mentors. As in the Seegers and Boekaerts (1996) study, many of the women increased in the self-confidence they needed to succeed. The role models of the female personnel involved in the FIG helped dispel myths of mathematics as a male domain. Our work thus parallels the conclusions of Hart (1992) and Jacobs et al. (1998) who found that when women pursue fields that require mathematics, they often do so because of interested teachers. Many of the women experienced increased self-efficacy—valuing their own capability to do the mathematics. As one young woman from the FIG proclaimed:

> In [secondary school] if I had found a career that required math, I would say, 'That's got math in it. I'm not going to do that.' But like last week when I was looking at possible degree areas, when I saw one with math, I realised I am not scared of it any more. I am not running away from it.

The psychosocial mentoring in the FIG was not the only factor that helped the women succeed. Richard and Jill worked with the students to create the mathematics together. Richard and Jill used problems that enabled students to see how calculus could be important in their lives. Class members experienced satisfaction with working mathematics problems and were pleased with their successes. The women talked freely about mathematics during class, went to the chalkboard to share their solutions, and showed no inhibitions about asking questions. Carmen, Maria, and the others did not limit their conversations to finding solutions to problems but also talked about why they chose certain approaches to problems over others. Maria particularly was an example of a student who needed to make connections in her thinking. She had a deep need to understand the procedures of calculus. Our research thus succeeds in applying findings from Barnes and Coupland (1990), Becker (2003), Jacobs and Becker (1997), and Belenky et al. (1986) who suggested that many women learn mathematics through making connections to their experiences while building relationships with others in their learning environment. The women in our study learned through finding applications for mathematical concepts before learning the abstractions so they could understand why they needed to learn the concepts. Their hourly examinations emphasized concepts and applications along with procedures. Their scores on the final examination, which was one that contained mostly procedures, and their marks for the class (89% received a C or above) demonstrated that this professor′ s approach helped them to achieve as well as or better than other students in Calculus I.

Closing Remarks on the Social and Cultural Implications of the FIG Experience

We found that the same support structures that diminished psychosocial barriers to Carmen's and Maria's success as women also increased their comfort level in terms of race, class, and other factors—even though the classes were not homogeneous in terms of these variables. Yet what made the FIG special was that the encouragement and reinforcement came in a setting that emphasised dialogue, a quality that is not necessarily a top priority in a mathematics classroom. This dialogue allowed students to perceive commonalities and even at times to articulate epistemologies about the nature of their learning in mathematics.

As Collins (1991) concluded in her research, we found that an emphasis on the value of dialogue and empathy helped people understand each other's viewpoints. What happened in the FIG is congruent with Collins' (1991) description of empowerment:

> Each group speaks from its own standpoint and shares its own partial, situated knowledge. But because each group perceives its own truth as partial, its knowledge is unfinished. Each group becomes better able to consider other groups' standpoints without relinquishing the uniqueness of its own standpoint or suppressing other groups' partial perspectives. (p. 238)

Each of the young women discussed was able to understand her peers' diverse experiences without devaluing her own background. As Carmen's case demonstrated, the women's experiences with calculus unlocked other barriers. The students began by feeling concern for each other as women engaged in a shared but difficult task. By the time Carmen faced financial difficulties that affected her campus residence, the bonds were strong enough that students wanted to support her in other ways as well. Similarly, Carmen was able to negotiate the cultural differences between her home and school environments when she began to see that she could maintain old ties while finding different commonalities with her university peers. Maria discovered that the group provided encouragement when her family could not understand her motivation to remain in university.

The strong ethic of collaboration within the group compensated for some of the women's restrictive gender role experiences with friends and family. As Willis (1998) discussed in her descriptions of mathematics curricula, our challenge is to modify our mathematics curriculum to improve the educational experiences of a broad range of social groups and to work justly to address the interests of all, regardless of ethnicity, social class, and gender. In the present study, instead of feeling isolated as women in mathematics, or women of low income or class, or women of colour, the students were able to find commonalities. These commonalities inspired all of them, individually and collectively, to succeed better than they might have otherwise. This success opened more career opportunities to them instead of limiting their selection of undergraduate degree programs.

Acknowledgment

The research reported in this paper was supported by the National Science Foundation under grant No. HRD-0086310. The opinions expressed do not necessarily reflect the view of the foundation.

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