ABSTRACT

LAMBERTUS. AMANDA JANE. Characterizing Gender Diverse Graduate Mathematics Departments as Communities of Practice. (Under the direction of Dr. Hollylynne Lee and Dr. Karen Keene.)

The purpose of this study was to characterize mathematics departments that graduate a relatively large percentage of women doctorates. Through a collective case study of six graduate departments, and an in-depth case study of one department, the researcher highlights six characteristics of these mathematics departments and their descriptive elements.

The participants are a collection of Directors of Graduate programs, graduate students, and faculty members. Graduate students from all six departments participated in an open-ended on-line questionnaire about their experiences and perceptions of the graduate mathematics department within their respective university. Directors of Graduate programs, graduate students, and faculty members participated in qualitative interviews. Further data was collected from the departmental and university websites.

The theoretical framework is the Communities of Practice work (Wenger, 1998; Wenger et al., 2002). It consists of three aspects; domain, practice, and community. Each of these aspects is developed in relation to the other two. The Communities of Practice framework provides a fluid and dynamic research lens to study an environment that supports a knowledge base and fosters relationships with a group of people.

Findings indicate that the graduate mathematics departments provide a variety of structures for supporting students and faculty, and that the departments foster relationships

through many opportunities for social and academic interaction. In addition, members are attracted to these departments for both personal and universal reasons, including the wide variety of research options for students and faculty, and guaranteed funding for most graduate students.

Characterizing Gender Diverse Graduate Mathematics
Departments as Communities of Practice

by
Amanda Jane Lambertus

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APPROVED BY:

Hollylynne Lee
Co-Chair of Advisory Committee

Karen Keene
Co-Chair of Advisory Committee

Sarah Berenson

Susan Bracken

Stephen Campbell

BIOGRAPHY

Amanda Jane Lambertus was born in Terre Haute, Indiana on August 19, 1978. She grew up in Terre Haute and graduated from Terre Haute South Vigo High School in 1996. She attended and graduated from Indiana University, Bloomington in May, 2000 with a Bachelor of Art degree in Mathematics. Upon graduation, Amanda returned to Terre Haute and taught one year of high school mathematics at North Vigo High School. After the first year, she moved to Beaufort, North Carolina and taught Pre-Algebra, Algebra I, Geometry, Algebra II, and Technical Mathematics for three years before returning to graduate school at North Carolina State University in August 2004.

While at North Carolina State University, Amanda pursued a Master's of Science in Mathematics Education and graduated in 2007 and continued her graduate education pursuing a doctoral degree in Mathematics Education while working as a Teaching Assistant for Intermediate Algebra. In addition to teaching, Amanda has worked as Research Assistant throughout her graduate studies on the NSF funded projects, "Girls on Track" and "Markers of STEM Success". From this work, Amanda has co-authored several papers and presented at numerous national conferences and submitted publications to journals.

Upon receiving her degree, Amanda plans to pursue her research interests in equity and the success of all students through a university position as well as continue her work with pre-service and in-service teachers.

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LIST OF SYMBOLS AND ABBREVIATIONS

CoP – Community of Practice

DGP – Director of Graduate Programs (or administrative equivalent)

GSOQ – Graduate Student Online Questionnaire

NSQ – New Student Questionnaire

RA – Research Assistant

REG – Research Experience for Graduate Students

REU – Research Experience for Undergraduate students

STEM – Science, Technology, Engineering, and Mathematics

TA – Teaching Assistant

UMD – University Mathematics Department

CHAPTER 1: INTRODUCTION

Imagine a mathematics department where graduate students and faculty members are united by their passion and interest in mathematics, connect with one another through interactions and meaningful relationships, support each other academically through formal and informal mentoring, and collaborate to create an environment where enthusiasm, ingenuity, and student success can flourish. Now imagine that department to have an unusually large percentage of women in both their student body and their faculty members. This paper attempts to show that this is a reality in some places and not imagination.

Historically women and girls have been under-represented in mathematics at all levels. However, due to efforts in education reform, women and girls are represented as well as men and boys in upper-level high school and undergraduate mathematics courses (U. S. Department of Education, 2007). Unfortunately, at the graduate level, the disparity between men and women achieving doctorate degrees in mathematics is much greater. Table 1 reports this disparity for several groups of the Science, Technology, Engineering, and Mathematics (STEM) fields as well as some of the social sciences. By looking over the span of several decades, one can see that the percentage of women earning doctorate degrees in the physical, biological, and social sciences, mathematics, engineering, psychology and education has increased. This increase is most prominent among the social sciences and education. However, the biological sciences (which include the medical sciences in this table) have more women earning doctorate degrees than the social sciences as a group. The biological sciences have also made the most progress of the STEM fields in terms of increasing the percentage of women earning doctorates. The other three categories have made improvements as well.

Table 1
Percentage of Women Earning Doctorates in Selected Fields

Field	1920-1961[a]	1979-1980[b]	1989-1990[b]	1999-2000[b]	2004-2005[b]	Change in Percentage from 1920-1961 to 2004-2005
Physical Sciences	10%	12.3%	19.1%	25.3%	27.9%	17.9
Mathematics	8%	13.8%	17.8%	25.3%	28.5%	20.5
Engineering	0.5%	3.9%	9%	15.5%	18.7%	18.2
Biological Sciences	11%	25.5%	36.8%	44.3%	49.0%	38
Social Sciences*	13%	27.0%	32.9%	41.2%	42.8%	29.8
Psychology*	18%	43.4%	58.9%	67.7%	71.3%	53.3
Education*	19%	43.9%	57.3%	64.2%	66.7%	47.7

Note: * not a STEM field, used for comparison, a: Harmon & Soldz, 1963, b: United States Department of Education, 2006

Statistics have consistently shown that the mathematics community is not diverse in race, ethnicity, or gender (De Welde, Laurson, & Thiry, 2007). But, statistics do not tell the entire story. Women have made great strides in terms of STEM participation at both the university level (US Department of Education, 2006) and in the workforce (Babco & Ellis, 2004; Monroe et al., 2008). However, qualitative studies (see Monroe et al, 2008; and the Massachusetts Institute of Technology Report, 1999) suggest that women still face large barriers in academia and the workforce, including issues of gender inequity in both these settings (Monroe, et al, 2008). Less is known in the research literature about what seems to work well for women and keep them engaged in university settings, particularly within mathematics departments. Further research is needed to examine the practices of successful graduate mathematics departments with relatively high percentages of women doctorates. This study attempts to add to the literature by providing a basis for which mathematics departments can use to aid in the success of all their students.

Purpose of the Study

Research centered on women in STEM has largely focused on the reasons why women choose to leave STEM careers and fields of study (see Blickenstaff, 2005; Herzig, 2002; 2004a). But there are women who choose to stay, and are successful in their academic pursuits and careers. Also, there are mathematics departments that foster environments in which women want to participate. These programs are actively trying to increase gender diversity in their departments. As a result of increasing the gender diversity with their departments, they are increasing diversity within the mathematics community as a whole, which is traditionally male. Therefore, this research study focuses on characterizing six graduate mathematics departments who have a history or reputation of producing larger percentages of women graduates with doctorate degrees and what they do that aids in the success of all students.

In conducting this study, the researcher hopes to discover those practices which encourage students to attend and graduate from these programs with doctorates. The study also investigates how members of those mathematics departments experience and perceive the departments' climate and the integration of its members.

The research addresses the issues surrounding women's under representation in graduate mathematics programs and as a result looks for solutions to increasing the number of women who participate. “Under representation” is a broad term and needs to be more clearly defined, because one can argue that women are not under represented and that their numbers have increased in graduate mathematics programs throughout the country over the last few decades (Jackson, 1991, 2004a). This study also focuses on the graduate mathematics departments of Research Intensive and Research Extensive universities (as defined by the Carnegie Foundation 1999) because these universities carry out major gate keeping tasks by training the next generation of Ph.D. mathematicians as well as encouraging or discouraging students to pursue careers in mathematics (Leggon, 2006).

Overview of Approach

There is no single solution to increasing the number of women participating in STEM. Therefore, the research will take a holistic approach to studying graduate mathematics programs and the students enrolled in those programs. The holistic lens for this research is the theory of Communities of Practice and the role those communities play in recruiting and retaining women (Lave & Wenger; 1991; Wenger, 1998). A community of practice is a collective learning environment, which, over time, results in practices that reflect the pursuit of enterprises, such as becoming a mathematician, and the accompanying social connections within that particular group (Lave & Wenger, 1991; Wenger, 1998). Membership within a community is essential to a social participation learning perspective. The influence of the Community of Practice framework seems to be evident in the current efforts of the American Institute of Mathematics conference workshop on increasing the number of women in graduate mathematics programs (Herzig, Cohen, & Manderscheid, 2006) as well as the Carnegie Initiative on Doctorate Education (Golde, & Walker, 2006).

Both of these models are based on the work of Lave & Wenger (1991) and use the ideas associated with apprenticeships and 'stewards of the discipline' (respectively).

This study involves four phases of data collection and several different types of data collection. Each of the phases and data helps to create a holistic picture of the departments participating in the study, and answer the following research questions.

R.1 *What are the characteristics of graduate mathematics departments that have a relatively high percentage of women doctorates in mathematics?*

R.2 *How do the characterizations of the graduate mathematics departments influence the graduate students and faculty members' experiences of the community within one particular large mathematics department?*

R.3 *How are the three aspects of the Communities of Practice framework related to the characteristics of the graduate mathematics departments?*

The study uses a sample of six University Mathematics Departments [UMDs] and will include a variety of data sources. The data sources will allow for a cross section of participation of UMDs members' voices to be heard.

Definitions of Important Terms

Before continuing, it is important to explain how some of terms in this study are defined. First, what does it mean for a mathematics department to be successful in terms of producing women doctorates? In this study, success was measured as those departments where 25% or more of their mathematics doctorates were awarded to women. Second, an under-represented population in the field of mathematics is one in which their percent of representation in the mathematics community is below their general population percent (De Welde et al., 2007). These descriptions of success and under-represented populations will be the baseline used later in the literature review and data collection sections.

Third, the theoretical framework used in this study is the Community of Practice work (Wenger, 1998, Wenger et al., 2002). The following definition is used: a community of practice is a "group of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger, et al., 2002, p. 4). In this study, this framework will be used to examine the university graduate mathematics department.

Challenges

The first challenge of the study was to identify universities which have large percentages of women earning mathematics doctorates. The most recent published data does not include the last couple of years. Therefore, the researcher used data from the 2004-2005 school year. Unfortunately, this may exclude universities that have made attempts in the last couple of years to improve the number of women in their programs.

A second challenge is a result of the current demographics of mathematics departments. While these departments are known for having relatively large numbers of women, members of other non-Asian minorities may be underrepresented, and therefore not represented in the group of participants. Different ethnicities and races of students as well as individuals may experience their department's dynamics differently even if they seemed to have the same experiences as others.

This research is not disaggregating the graduate students into smaller more defined groups for several reasons. It is difficult to find demographic data on historic trends which look at race or ethnicity in conjunction with gender. Most large demographic surveys look at either gender or race/ethnicity (Leggon, 2006). This research study also does not differentiate between students that are US citizens and international students. This is a disadvantage to the study, as students of different races, ethnicities, and cultural backgrounds experience the academic environment differently and may face different “microinequitites” (Leggon, 2006; Sandler, 1999).

Conclusions

Research that focuses on the positive aspects of mathematics departments and their graduation rates of women doctorates can influence several fields. First, the study is situated within higher education and the policies concerned with recruitment and retention of underrepresented groups, including women. It is possible that this study could serve as an example for other gender diversity studies in STEM fields, improving the quality of STEM education at the doctorate level for women. Second, the study is focused on “success” stories in mathematics. This means that the results of the study could outline measures that other mathematics departments might employ to increase the diversity in their programs and provide success for all students.

In addition, this research contributes to the mathematics education research by providing a glimpse of the educational environments that occur in the mathematics graduate programs with high percentages of women. This study does not look at how women learn graduate mathematics, but rather aspects of the pursuit of graduate mathematics at particular universities by both males and females. At the graduate school level, and even at the undergraduate level to some degree, mathematics becomes a choice. Women either choose to study it or they choose not to. This research will help us to understand why specific educational environments are appealing to large numbers of women choosing to study mathematics at the graduate level. If the Community of Practice framework is successful at the highest level of education for women, it may be beneficial to examine mathematics classrooms at the K-12 level using this type of framework for improving women's success in higher level mathematics.

The American Mathematics Society (AMS) reported 32% of doctorates awarded in the mathematical sciences (mathematics, computer science, and statistics) went to women during the 2005-2006 school year (Kirkman, Maxwell, & Rose, 2007). While the percentage of women earning doctorates has drastically improved over past decades (see Harmon & Soldz, 1963), there is still room for improvement. This work provides a different perspective in the research on women in mathematics and STEM disciplines in general. Eventually, the knowledge gained here may help other departments increase the number of women enrolled and completing their graduate programs.

CHAPTER 2: LITERATURE REVIEW

Introduction

Women and minorities have been consistently underrepresented in the field of mathematics, regardless of the numbers of students enrolled in graduate mathematics programs. The underrepresentation of women has been punctuated by the overall decline in the number of students with US citizenship pursuing mathematics doctorates (Earl-Novell, 2006; Kirkman, Maxwell, & Rose, 2007; Herzig, 2002). In order to help the mathematics field flourish, a healthy (i.e. diversified) mathematics community is needed. Such a diversified community can aid the United States in positioning itself to compete in a technological and quantitative world (Earl-Novell, 2006; Herzig, et al, 2006). This need for diversification is driven not only by a desire for an increase in the United States' intellectual capacity, but also by economic and demographic pressures, including the decline of a majority, white males,(Bass, 2003; Herzig, et al, 2006) in terms of numbers.

In order to understand how to create these healthy communities, Science, Technology, Engineering and Mathematics (STEM) departments need to become familiar with what motivates students' participation in STEM at all levels, and what factors contribute to the success of women and their participation through graduate school. Major contributors to the research in the STEM community that focuses on women are from a variety of fields; psychology, sociology, women's studies, mathematics education and higher education, as well as the science technology engineering and mathematics fields (Becker, 1990; Blickenstaff, 2005; Earl-Novell, 2006; Herzig, 2002, 2004a, 2004b; Marx & Roman, 2002). In addition, important works addressing college student attrition in general can be found in the higher education, sociology, and psychology fields (Lovitts, 2001; Tinto, 1993). This literature review uses sources from all these fields in order to help understand the different perspectives of research on women in STEM fields.

The next few sections of the literature review explore different perspectives from the research on women participating in STEM, and in particular mathematics. However, first, the literature review defines the different ways attrition from school, fields, and careers is measured and why attrition is important to study. The subsequent sections explore the research perspectives as the K-12 level, women's participation in academia beyond graduate school, and research focused on the institutional characteristics and social influences. The chapter then investigates the recruitment of women in STEM and ends with a discussion on the Communities of Practice Framework for studying faculty and students' participation in graduate mathematics departments.

Attrition

Discussions of attrition must first elaborate on how it is measured, and placed within doctoral education. Difficulty in situating attrition is linked to the fact that many institutions define doctoral study and doctoral students differently (Lovitts, 2001, National Research Council, 1996). There are three methods for defining students who are pursuing PhDs in American Institutions. The American Model considers students who enter their first year of doctoral study as members of the PhD program, the German Model, also prevalent in the United States, counts students as PhD students after they have been admitted into candidacy, and the M.A.-First Model is based on the idea that a student enters a PhD program only after receiving a master's degree (National Research Council, 1996).

The differences among the three models make it difficult to measure attrition across different departments within one university or similar departments across many universities. In addition to difficulty in counting doctoral students, the definition of attrition creates issues with how it is measured. Attrition is defined by the "reduction in the number of students pursuing a PhD" (National Research Council, 1996, p 14). However, the actual measurement of attrition depends on who is doing the measuring and what the purpose of that measurement is. For example, if a department head is interested in the number of students that are leaving his program, he may determine the number of students who enter the program in a given year (or range of years) and from those students, count those that have either completed degrees or are still enrolled in the program. This method measures the student attrition for that particular department; however, it does not take into account where those students who left may have gone. More specifically, it also does not factor in graduate students that left that particular program and went to another university. These students are therefore counted as an attrition statistic on one end, and an entering or transfer student on the other end.

Large attrition rates have been reported for women in STEM majors at both the undergraduate and graduate levels (Herzig, 2004a; Earl-Novel, 2006). Any student that leaves their graduate study after several years of study represents an inefficient use of personal and university resources, in terms of time and money, (Earl- Novell, 2006; Herzig, 2002; Tinto, 1993). As long as these large attrition rates are reported, the reasons for women and other non-Asian minorities leaving need to be explored. It can be argued that the students who leave are expressing their interests in other subjects, or a lack of interest in

STEM majors. However, Herzig (2002) argues that it is possible that women leave graduate mathematics study because they are unable to negotiate the graduate community associated with their chosen fields. This community may intentionally or unintentionally impose expectations or cultural norms on students in which they are unable or unwilling to meet and as a result, the students leave, but not because of a lack of interest or ability (Herzig, 2002). However, taking a positive perspective, it is also interesting to study the many students, male and female, who remain in their fields and successfully navigate the graduate mathematics programs in their respective institutions as this study does.

Students leave their chosen fields in two waves. First, early leavers leave before they have completed their master's degrees or earned entrance into the PhD candidacy. Second, later leavers leave much later in their programs, often after completing qualifying exams. Early leavers left for the following reasons, (1) no Ph.D. was intended in the first place, students left after completing the masters degree, (2) students switched fields of interests, (3) students switched institutions, (4) the department and student were mismatched, (5) the students were frustrated and expectations were not met, and (6) professionals returning to school had trouble adjusting to the academic climate (Duffin & Simpson, 2006; Nersad & Miller, 1996). While late leavers from the fields left for different reasons, (1) they were undecided about a dissertation focus and therefore not dedicated to finishing the degree, (2) the motivation to finish a long term goal was diminished over time (3) the advisor –student relationship was unfulfilling, (4) lack of financial support in the late stages of their education, and (4) the departmental climate (Geraniou, 2010; Nersad & Miller, 1996).

K-12 Research Perspectives on Girls Participation in Mathematics and Science

This section presents research on the possible reasons for girls' lack of interest in science and mathematics during the Kindergarten through 12th grades. It focuses on historical and current discussions on academic achievement, classroom climate, and biological beliefs. Understanding the research on gender at the K-12 level is important because it adds to the understanding of girls' achievement during the early years of their educations. It also addresses some of the issues girls' and young women face during those years while pursing advanced science and mathematics courses. The following issues will be discussed, (1) mathematics as a gatekeeper, a historical and current perspective, (2) biological beliefs about girls' ability in mathematics, (3) attitudes associated with students in mathematics, (4) academic achievement as an influence in women's interests in STEM, and (5) classroom environments and their effects on young women's attitudes toward mathematics.

Mathematics as a Gatekeeper: An Historical Perspective

Mathematics and science courses have been and continue to be gatekeepers to higher education and many careers (Blickenstaff, 2005; Briggs 2006). Sells (1980) states that beginning as early as age 11, mathematics becomes a filter for further education and career choices. It is during these years that young women begin to doubt their mathematical ability and therefore may begin to filter out of mathematics courses by choice (Cobb, 1979; Ernest, 1976; Sells, 1980), which may limit their choice of undergraduate majors (Sells, 1980). Algebra used to be the gatekeeper for upper level mathematics courses, but today, most students take Algebra I as part of their high school graduation requirements (Gray, 1996; U.S. Department of Education, 2007a).

Today, the ideas centering around women and algebra as a gatekeeper no longer seem to be relevant. First, women are taking the same mathematics classes as men in near the same numbers; see Table 2. Therefore algebra is no longer serving as a gatekeeper to higher mathematics in terms of women's participation. However, algebra is still seen as a gatekeeper to higher mathematics for all students (Briggs, 2006). Further, new ideas about mathematics as a gatekeeper are still evolving; algebra as a gatekeeper for calculus bound students (Briggs, 2006).

Table 2
Percentage of high school graduates (2003-2004) and highest level of mathematics

	Highest level of Mathematics course taken since 9th grade [a]				
	no math	basic math/pre algebra	through algebra II	trigonometry, statistics, pre-calculus	calculus
Men	0.7%	5.9%	45.2%	33.6%	14.5%
Women	0.4%	3.8%	44.0%	38.5%	13.2%

Note: a – adapted from U.S. Department of Education (2007b)

Biological Beliefs about Women's Mathematical Ability

External sources such as classroom instruction or environments can influence students' academic achievement. One historical research perspective that removes responsibility from external sources is a belief that boys are just better at mathematics and science than girls through their innate abilities. This perspective can be linked to biological beliefs about the differences between men and women. Fundamentally, this biological beliefs perspective encompasses the viewpoint that women lack the innate ability to do mathematics when compared to men (Seymour & Hewitt, 1997). A study published by Benbow and Stanley (1980) reported large gender difference in mathematical performance existed at the junior high level. They refuted the claims of other researchers who felt that gender differences were a result of differential course-taking in mathematics. They argued that at the junior high-level boys and girls would have had the same mathematical experiences and formal education. Unfortunately, this study received a large amount of media attention. Therefore, this study has been discussed in detail and reasons for choosing an alternative viewpoint have been provided (see Eccles & Jacobs, 1986). Some of the reasons included the fact that multiple classrooms were used in the study, without controlling for curriculum or teacher influence on students' learning. However, seventeen years later, Seymour and Hewitt (1997) found evidence of the biological debate still in place on many college campuses for the reason that women were not successful in the sciences.

The debunking of the research however, does not 'debunk' societal conventions and beliefs that men are naturally better at mathematics. Recently, the former president of Harvard University, Lawrence Summers drew public criticism for stating that the innate differences between men and women might be a reason for why women are not as successful as men in science and mathematics careers (Summers, 2005).

Young Women's Attitudes towards Mathematics and Science

Connected to academic achievement, in both K-12 and college classrooms, are students' attitudes towards course subjects. Oakes (1990) has traced the attitudes of girls throughout their educational careers. She reports that elementary school girls through high school girls possess more negative attitudes than boys towards mathematics and science careers (Oakes, 1990). One possible reason for girls' and young women's negative attitudes is what they perceive as the social costs of aspiring to STEM careers (Oakes, 1990). For example, Sax and Bryant (2006) reported that interest in raising a family caused women to shift toward more gender typical fields, and away from STEM fields.

Women often "take into account society's contradictory prescriptions for powerful women" (Lips, 2007, p. 56) when considering roles as leaders in male-dominated fields. This aspect of women's interests connected to the social costs of choosing a gender a-typical career is that women show a greater interest in people and helping people, while men on the other hand are more interested in things they can touch or manipulate, in other words physical objects (Oakes, 1990). Women often feel obligated to make contributions to society (Friedman, 1995). These interest patterns might help explain why some women may not be as interested in mathematics and science careers and why they view those subjects more negatively than men.

Academic Achievement

Academic achievement is an important factor when looking at women's interest in STEM majors and careers, because in the past, high achievement in mathematics and science was a predictor of women's entry into male dominated fields (Peng & Jaffe, 1979). Traditionally research on gender and mathematics education focused on the achievement levels of boys and girls. In a review of 36 studies prior to 1975, Fennema (1979) concluded that there was little evidence of gender differences related to mathematics achievement prior to the secondary school; however, the trend suggested that boys excelled in higher level cognitive tasks while girls excelled at lower level cognitive tasks (Armstrong, 1981;

Fennema, 1979, Oakes, 1990). By examining the content of mathematics test, one can see that girls' average score on arithmetic is better than boys, they score about the same in algebra, and girls have slightly lower scores in geometry (Burton, 1995). If one looks beyond the average scores for the gender, one can see that the distributions of scores for mathematics tests often overlap. Girls display as full a range of mathematical talent as boys (Burton, 1995).

Achievement studies in mathematics during the 1960s and 70s, which claimed that men were superior, were of special interest in relation to the gender differences in careers. Fennema (1979) felt that "beliefs about male superiority [in mathematics] were no longer accepted as valid in all situations" (p. 390). Gender differences in achievement do not appear at the elementary level in either mathematics or science courses (Oakes, 1990). In junior high school, some differences begin to appear, however none of them are major differences, between girls and boys mathematical achievement (Oakes, 1990). In fact girls scored higher on average on math tests than boys until junior high (Burton, 1995).

Some earlier large-scale studies reported gender differences in mathematics achievement such as the International Study of Achievement in Mathematics, (1967) and the National Assessment of Educational Progress (Husen, 1967; NAEP, 1975). More recently, the TIMSS, 1995 and PISA, 2006, studies have not reported gender differences among high school students in the United States (Baldi, Jin, Skemer, Green, & Herget, 2007; Kelly 2002). Although there is some evidence to indicate that girls' and boys' mathematics achievement and course taking differences are minimal, there are small differences that favor boys on standardized tests (Lacampagne et al, 2007). The largest of these gender differences occur among a small percent of students at the most advanced levels (Lacampagne et al., 2007)

In the past, some researchers looked at students' course taking trends as well as test scores (Berryman, 1983; Fennema, 1974; Oakes 1990). They found that as students get older and course taking starts to differentiate, wider differences begin to appear between men and women's mathematical achievement (Oakes, 1990). Not only does course differentiation appear, but girls choose to take fewer advanced mathematics and science courses, often stopping with the required courses, while the boys have been more likely to take advanced mathematics, science and computer science courses (Oakes, 1990). It seems logical then that women and men would have different mathematical achievements but that these differences are more a result of discriminate course selection than innate ability. However, as Table 2 showed, these differentiations in course taking are no longer a concern.

Classroom Environments at the K-12 Level

Another factor which affects young girls' and women's attitudes toward mathematics and science is the classroom environment. This section is going to examine the effects of four aspects of the classroom climate: (a) curriculum and materials, (b) teacher-student interactions, (c) gender division in the classroom, and (d) instructional strategies (Fox & Soller, 2001).

Research on curriculum and materials includes an examination of the role of textbooks and the images of gender they present in mathematics and science classes (Fox & Soller, 2001). Historically, textbooks exhibited sexist stereotypes, mathematics books were "likely to portray boys as active and girls as passive" (Federbush, 1974 cited in Fox & Soller, 2001, p. 15). For example, boys were pictured participating in a sporting event, while girls would be grouped by appearance, such as the color of their eyes. However, over time, mathematics books included girls in more problems and examples rendering the texts "relatively free of bias against girls starting in the early 1980s" (Nibbelink, Stockdale, & Mangru, 1986 cited in Fox & Soller, 2001, p. 15).

A different look at curriculum examines the various 'tracks' students can enroll in during high school. For example, in North Carolina there are three different routes (curriculums) students can take to graduation, each has different requirements, and students can take different courses (North Carolina Department of Public Instruction, 2006). Enrollment in the various curriculums influences subsequent opportunities for women in STEM since in many cases science and mathematics courses are large determinates of the different curriculums (North Carolina Department of Public Instruction, 2006; Oakes, 1990). Further, the total number of science and mathematics courses taken during high school is related to both women's and men's entry into traditionally male dominated fields, in other words STEM fields (Peng & Jaffe, 1979).

While curriculums can dictate the courses students take, teachers play an important part. Teachers may be the single most influential aspect on students' learning and enjoying mathematics (Fennema, 1979). Teacher-student interactions include how teachers interact with students, with whom they interact, and how students view those interactions. Some (e.g., Fennema, 1979; Fox & Soller, 2001) have noted that teachers' interactions with students are more often focused on boys rather than girls. This interaction includes feedback, encouragement, praise, as well as blame and discipline (Fennema, 1979; Fox & Soller, 2001).

As a consequence, "high achieving girls receive significantly less attention in mathematics than high achieving boys" (Fennema, 1979, p. 397). Based on the result of Leinhardt, Seewald, and Engel's study (1979, cited in Eccles & Jacobs, 1986), in the past boys received as much as thirty-six more hours of formal mathematics instruction than girls by the seventh grade.

The third category under classroom environment is gender division. Gender division means that the number of boys enrolled in a course far exceeds the number of girls. Gender division in this respect refers mostly to the unintentional self segregation, when alternate curriculums enriched with advanced mathematics and science courses exist. These different tracks allow students to choose which courses they want to take, and as a consequence advanced mathematics, physics and computer science courses are often gender segregated (Fox & Soller, 2001). One feature that intensifies this type of division is that teachers may have a tendency to assign high achieving boys to top math groups and classes more frequently than they assign high achieving girls (Oakes, 1990). This does not mean that girls are not taking advanced math nor are they not in top mathematics groups.

The final category of classroom environment is instructional strategies. Traditional classrooms are teacher centered, in which the teacher is perceived as a source of knowledge, and little attention is paid to learning differences or student knowledge (Fox & Soller, 2001). This type of environment may be more analytical and favor boys more than girls (Fox & Soller, 2001). Researchers have suggested that because STEM subjects are taught often as abstract and disconnected from each other and from people, these subjects do not appeal to women (Oakes, 1990).

It has been suggested that women enjoy working in collaborative environments more than competitive ones, and that these collaborative environments encourage women's mathematical growth (Fox & Soller, 2001; Friedman, 1995). The down side to cooperative learning groups and collaborative environments is that they can still put women at a disadvantage. The instructor needs to be careful when assigning boys and girls to groups. If women are still outnumbered by men, they may not fully participate or they may find that their voices are drowned (Fox & Soller, 2001; Friedman, 1995).

Student's Perceptions of Adults in STEM Fields

The first studies exploring student's stereotype images of scientists or mathematicians date back to the 1950s. In their first study, Mead and Metraux (1957) asked what American secondary students thought about science and scientists. Their findings indicated that students felt that the scientists are essential to our nation. They also found that students thought scientists had to work hard, and were only occasionally rewarded. This type of work was respectable, but it had little attraction for high school students (Mead & Metraux, 1957).

Nearly 40 years later the research concerning images of scientists and mathematicians has continued, including a discussion during the 1990s about research concerning the images of mathematics and the people who do mathematics (Picker & Berry, 2000). In their study, Picker and Berry describe the different views of mathematicians that 12 -13 year old (middle school) students held from five different countries. They conclude that a number of stereotypical images are held in common by students from all five countries. These images included two different types of drawings: what a mathematician would look like if they were not a teacher and those of mathematicians at work that were teachers. Further these drawings were categorized into seven images of mathematicians: “mathematics as coercion, the foolish mathematician, the overwrought mathematician, the mathematician who can’t teach, disparagement of mathematicians, the Einstein effect, and the mathematician with special powers” (Picker & Berry, 2000). Each of these categories detailed negative images that students create concerning mathematics. These images can be powerful factors in why students choose not to pursue mathematics at any level. These images and the associated stereotypes, e.g., white lab coat, eyeglasses, facial hair, symbols of research such as books and scientific instruments, do not make the field attractive to students at the lower levels (Chambers, 1983). It is possible that unless students change their images, they may not pursue mathematics in college or as a possible career.

Conclusions on K-12 Research Perspectives

In the past, mathematics has been a significant gatekeeper at K-12 school level for girls and young women pursuing college degrees. Today, women are achieving the same scores and taking the same courses in comparable percentages as men in mathematics and science. Another belief has also been refuted in the research, that men are naturally superior to women in mathematics. However, other factors such as the classroom environment have some influence on women’s performance in mathematics. These factors include the strategies and beliefs of the classroom teacher, curriculum and materials, interactions between students and teachers, gender division within the classroom, and instructional strategies. Each of these factors continues to contribute to students’ success in the STEM fields as the collegiate level as well, and will be explored further in the section on *Research Perspectives involving University Characteristics and Social Influences.* The next section examines barriers to women's success at the university level in STEM fields. This perspective is explored second because students at the graduate level observe their faculty members experiences, sometimes using these observations to make judgments about their own futures.

Women's Participation in Academia

This section of the literature adds an essential perspective to the chapter. It is important to understand the barriers and discriminations that adult women face in academia in the STEM disciplines as well as other areas. This perspective takes into account social aspects of the disciplines and their respective departments. Undergraduate and graduate students observe their professor's life-styles and work ethics while they are in enrolled in school. They notice what types of behaviors are rewarded as well as the happiness of their professors. Students are not always aware of all the nuances associated with faculty members and department climates, but they are aware of what they see and hear. The graduate school socialization process includes students' conceptions of academic careers and faculty members' roles (Austin, 2002). Therefore, it is crucial to understand what women faculty members feel they must overcome to be successful in their respective institutions. Much of the research discussed in this section is qualitative in nature, because while statistical data provides the reader with a more positive picture of women's participation in STEM, qualitative data provides the reader with women's stories.

Types of Barriers for Women in STEM Fields

Some of the community expectations in academia may be seen as barriers to women's participation in the STEM fields. Research on barriers to women's participation in the sciences spans at least three decades (See Hall & Sandler, 1982; Harding, 1991; Sadker & Sadker, 1994; Seymour & Hewit, 1997). Eisenhart and Finkle (1998) outline several barriers to women's participation that have been discussed in the literature.

- Stereotype of scientists as nerdy and male
- Chilly climate of classrooms and degree programs
- Cultural definition of women as "people who leave" STEM fields
- Known manipulation of findings for both corporate and political gain
- Systematic exclusion of non-Western, non-male interests and perspectives

Each of these barriers is discussed in relation to students' perceptions and experiences in the next section. However, it is important to think about these barriers from a faculty perspective as well.

The Chilly Climate Hypothesis, posited by Sandler (1999), states that an environment which dampens women's (or other groups') self-esteem, confidence, aspirations, and participation through the behaviors of others, referred to as "microinequities", is damaging to various fields, and members of such fields. Such a climate is also damaging to the STEM community (Blickenstaff, 2005; Herzig, 2002; Wenger, 1998). These behaviors could be overt, such as gender biased comments or sexual harassment, or more commonly subtle behaviors, such as lower expectations for women employees or students.

Chilly climate issues are not limited to the classroom where there are distinct roles for professors and students. Chilly climate issues can play out among the faculty members as well. In fact issues of chilly climate include "overt and subtle gendered communication patterns and behaviors by faculty members and students that disadvantage women" (Cooper et al., 2007, p. 634). These types of behaviors include encouraging men to participate more frequently during faculty meetings or in the classroom, using examples that reflect gender stereotypes, paying more attention to a woman's appearance than her accomplishments, and discrediting the accomplishments made by women (Cooper et al, 2007). These factors can create chilly climates for faculty member, but graduate students can also feel the effects of the chilly climate through personal experiences (discussed later) and through observing faculty relationships.

The remaining barriers from Eisenhart & Finkle's (1998) work are discussed using Etzkowitz, Kemelgor, Neuschatz, & Uzzi (1994) reorganization of the barriers. Etzkowitz et al. organized these barriers into different categories. They propose three types of barriers that women face at all levels of academics. The first category is the traditional socialization of women and girls. This socialization may be linked to the idea that women are seen as people who leave STEM fields (Eisenhart & Finkle, 1998). Second, the structure of the academic system and its relationship to the "chilly climate" phenomenon (ibid; Sandler, 1999) and the idea of systematically excluding non-Western, non-male interests and perspectives from the curriculum and research (Eisenhart & Finkle, 1998) and discriminatory employment practices. The socialization of women and girls is discussed in the following section, and the structure of the academic system is discussed in both this section and the following section. This paper does not address discriminatory employment practices in terms of who is hired and who is not.

Barriers to women's participation in STEM can be described in general as gender discrimination. According to Monroe, Ozyurt, Wrigley, & Alexander (2008) gender discrimination partially occurs through the practice of gender devaluation. Gender devaluation is a subtle process in which positions held by women "lose their aura of status, power, and authority" (Monroe et al., 2008). Another way of thinking about gender devaluation is that it is the act of down grading a researcher's work, publications, or other achievements because they are a woman (or a man). Gender devaluation occurs in part because there may be specific differences in the way that men and women are treated in the workforce and in academia (Hollenshead, 2003; Massachusetts Institute of Technology 1999; Monroe et al., 2008). Each of the previous articles, Hollenshead, Massachusetts Institute of Technology, and Monroe et al., explore these treatment differences at three large Research I universities; University of Michigan, Massachusetts Institute of Technology, and University of California at Irvine, respectively. The studies found that at all three universities, women are often underpaid in comparison to their male peers, have unequal access to space and resources, and are excluded from any substantive power (positions) with university administration (Hollenshead, 2003; MIT 1999, Monroe et al., 2008; Park, 2000).

As well as facing the barriers associated with attaining tenure track jobs, women may face a "triple bind" (Etzkowitz, et al, 1994, p.43) when pursuing advanced degrees. The bind consists of career aspirations, personal responsibilities, and requirements of the academic structure or institution. Women often need to balance and negotiate between the three facets of the triple bind. It is not that men do not have the same responsibilities as women, but they may feel less pressure in trying to balance the three. The extra pressure that women may place on themselves may stem from added responsibilities that men traditionally do not have, even though women in STEM fields often have the same career aspirations as men. For example, women are usually the primary caretakers of children and are often responsible for most of the household chores. The academic structure can also cause different problems for women than for men. For example, for a woman pursuing a doctorate degree, status changes from single to married and/or becoming pregnant can cause issues within departments and may cause negative consequences (Etzkowitz et al, 1994).

Critical Mass

Earlier it was stated that the gender discrimination is in part due to gender devaluation. One theory for remedying gender devaluation is to increase the number of women holding power positions, or by attaining critical mass (Etzkowitz et al, 2000; Monroe et al., 2008). Critical mass is the term for the belief that the disparity of women in STEM can be solved by getting more women (or other minorities) interested in STEM fields and careers. In the 1970s, affirmative action incentives had been largely influential in trying to get more women into traditionally male academic fields (Etzkowitz et al, 2000). The idea was to help the traditionally male fields attain critical mass. This theory of critical mass is used to address pipeline issues, recruit more women to the STEM fields, and increase their participation in STEM.

However, the term critical mass can be misleading. It does not mean that the gender composition of a department is split fifty percent women and fifty percent men. Critical mass is defined as “a ‘strong minority’ of at least 15%” (Etzkowitz et al, 2000, p. 106). It is believed that if 15% of the faculty is a minority group (either gender or ethnic minority groups), then it is enough for that particular minority group to influence the majority population (Etzkowitz et al, 2000). However, that 15% is in itself an ambiguous number; there are still many factors that can contribute to women’s underrepresentation within a department. For example if the 15% represents women from several different cultures, or if the women are self-isolated within their laboratories, there is still not adequate representation of women in the social fabric of department (Etzkowitz et al, 2000).

Career Trajectories

Women's personal responsibilities do not diminish their career aspirations; they may pursue different career trajectories than their male counterparts. One interpretation of a career trajectory is the path a person takes through education and apprenticeship toward a specific career goal. Some traditional paths that lead high achieving students into mathematics programs and graduate degrees follow taking advanced mathematics courses in high school, earning a mathematics bachelor's degree as an undergraduate, and then immediately pursuing a doctoral degree in their early twenties with no or little work experience in applying their previous mathematics degree. However, some veer from this path and may explore other academic majors, and work in other fields (though typically related to mathematics e.g. high school teacher, or engineer) prior to returning to graduate school to pursue a doctoral degree in mathematics.

Throughout the graduate school process there are several pivotal points in the career trajectories of students. The following transition points in women's educational experiences occur at the following four times "(1) the qualifying examination, (2) finding a research advisor, (3) negotiating a dissertation topic, and (4) deciding what is sufficient work for the granting of the degree" (Etzkowitz et al, 2000, p. 69). Women need to effectively navigate all four of these points and to be successful in pursuing their degrees in STEM fields. Geraniou highlighted "survival strategies" that students employed during each of the transition points (although her transition points are slightly different) (2010). The need for the strategies was most evident in her study when the students lost some form of external motivation. One of the most common strategies was self-reliance. This persistence and belief in overcoming obstacles along with a focus on coursework, working on campus and involvement in research, teaching and tutoring positively affect women's ability to be successful in STEM majors (Geraniou, 2010; Sax & Bryant, 2006). A second type of motivation that helps women make successful transitions between the stages of the PhD is external. In these cases, advisors and mentors often times proved to be the practical or emotional support (Geraniou, 2010). At each of the transition stages, students need support to make them smooth.

A second interpretation of career trajectories concentrates solely on the career paths themselves. Zuckerman's (1991, cited in Eisenhart & Finkel, 1998) study found that women and men of the same educational caliber searching for jobs tend to have different career trajectories. For instance female scientists are more likely to have their first academic careers in non-tenure track positions such as lectures or instructors, whereas men are more likely to immediately obtain tenure track jobs (Eisenhart & Finkel, 1998). In past decades, recent graduate students are facing a decrease in tenure-stream positions, and an increase in non-tenure track positions (Austin, 2002). This means that there are fewer jobs in which women have to compete with men. Also, women, who aspire to become members of academia, need to learn more about other opportunities outside the academy (Austin, 2002). More recently, of those students who received doctorates in the Mathematical Sciences during the 2007-2008 academic year and who took employment in academia in the United States, only 38% reported taking tenured or tenure track jobs (Clearly et al., 2009). To put this into perspective, the percentage of students taking jobs outside of academia was 26% in 2004 and has been slowly increasing (Clearly et al., 2009). Each year new students must complete with job seekers who took temporary jobs the previous year, making tenure track jobs a premium (Clearly et al., 2009)

Before women can choose careers in the STEM fields, they must first choose STEM majors and persevere in those majors. Regrettably, at the undergraduate level, research in the 1990's found that women who enter the university with an interest in STEM complete their degrees at a lower rate than their male counterparts (Burton, 1995; Linn & Kessel, 1996). But this attrition from STEM does not occur solely during college years, it starts much earlier. Several researchers refer to the educational pipeline (Berryman, 1983; Oakes, 1990; Sells, 1980). More specifically, Berryman (1983) discusses the scientific and mathematics talent pools.

This pool represents the students in which scientific and mathematics PhD graduates rise from. Berryman (1983) states that the pool appears first in the elementary school and reaches its maximum size by the ninth grade; throughout the undergraduate and graduate school, it declines substantially. In elementary school, membership in the talent pool is related to students' interest in STEM careers more than skill or ability in those subjects. During the middle school, the mathematics content and course sequences become more rigid. Membership in the talent pool is less secure and students "may be inequitably distributed among hierarchies of mathematics courses on the basis of race and economic background" (Akos, Shoffner, & Ellis, 2007, p. 238), which are not excluded by gender. By the end of high school, the membership is also related to advanced STEM coursework. Therefore, the period prior to high school is critical for encouraging girls to begin and continue studying advanced mathematics and science topics (Akos, et al., 2007; Berryman, 1983; Kerr, 1994).

Demanding Faculty Life Styles

The following discussion looks at the demands of faculty life-styles in academia in general. New faculty members experience multiple demands and stress associated with work overload (Austin, 2002). Both men and women have to juggle “multiple and sometimes conflicting professional responsibilities, and with achieving a balance between professional and personal lives” (p. 99). Adding to stress and professional responsibilities are the rigors of achieving tenure. Faculty members work long hours. In 2006, Colbeck reported that tenure-track women with children living at home reported working an average of 52.5 hours per week.

There is often a conflict between the tenure clock and a biological clock for women pursuing doctorate degrees in their mid twenties and early thirties (Etzkowitz et al., 1994). The career structure for academia science is compatible with youthful male achievement (Etzkowitz et al., 1994). It has been compared to a “force march” in the early years of employment, and only later, can a faculty member “slow down.” This is the opposite system that is often needed for women who wish to raise children (Etzkowitz et al., 1994). Women wanting to raise children, spend the early years of their careers sharing their time between family and careers. This can make the women appear less productive in terms of producing research and publications. However, as the children grow and become more independent, women have more time to dedicate to their careers, and become more productive during the later years of their careers. Men on the other hand typically do not have to split time between careers and family, as they are often not the primary care takers for young children. Therefore, they often have the flexibility to devote the early years of their careers to research and publications and “slow down” or take on different roles later.

Tenure involves being judged on three criteria over several years, research, teaching, and service (Park, 2000). Depending on the type of institution, these criteria are not all weighed equally. Some departments consider research the most valued criteria when promoting faculty members to tenure (Park, 2000). Park’s article does not address which types of institutions value research above the other two criteria; however, it is known that research is important to doctoral granting universities. It is important in two ways for successful promotion at research intensive and extensive institutions, it is necessary and it may be sufficient (Park, 2000). Within the realm of research, universities seem to have a ranking system of what they deem as most important to least important. The more “pure” the research the more valuable it is to the promotion system (Park, 2000). Some believe, as reported by Park, that research is the “only factor that *differentiates* faculty presumed to be equal in other respects…research performance is the only factor by which faculty can be *objectively* evaluated” (Park, 2000, p. 288)

Several issues concerning promotion for faculty are overlooked. These issues may be exacerbated when beliefs such as ‘everyone teaches and serves on committees’ are present, implying these activities are not as important for promotion as scholarly research. Faculty do not teach the same amount of courses or students, faculty members vary on the amount of effort they put into their teaching, not everyone serves on the same number of committees, or spends the same amount of time on them. In light of gender discrimination, teaching duties have fallen and continue to be given to women faculty members more than men (Park, 2000). Some women feel that the time and effort they devote to teaching and advising students is important and should be valued; they also feel that they do not receive ‘credit’ for these tasks (Monroe et al., 2008; Park, 2000).

Within certain fields or departments, women can be faced with the perceived consequences of choosing to get married or have children during graduate school or prior to tenure (Etzkowitz et al., 1994). Women graduate students and faculty members have reported that they thought they would be penalized for choosing to have children, perhaps being perceived as less serious about science (Etzkowitz et al., 1994). Marriage and young children have may have a negative effect on the probability of women entering tenure-track jobs, but family status does not appear to affect the faculty member eventually achieving tenure (Mason, Goulden, & Wolfinger, 2006). Meaning if married women or women with children choose to enter tenure-track jobs, they are able to achieve tenure at the same rate as single women.

Conclusions on Women’s Participation in Academia

Students’ perceptions of faculty roles and demands may influence their decisions to attend graduate school or to pursue careers in academia. Therefore, when determining why students leave or choose to stay in specific fields it is important to also look at the faculty. This section has addressed different types of barriers that women may face as well as the demanding life styles of new faculty members. Further, it looked at the theory of critical mass in achieving gender diversity in the STEM fields.

There are many possible reasons for women's attrition from STEM. The factors and influences that cause some women to shy away occur throughout the education process. This section focuses on women's experiences and participation in academia, while the previous one examines K-12 perspectives. In order to connect the two sections in terms of the moving from K-12 education to faculty positions, the literature review examines social factors and influences on undergraduate and graduate women enrolled in STEM courses or majors.

Research Perspectives involving University Characteristics and Social Influences

This section of the literature review focuses on the social reasons and institutional characteristics that influence women in choosing, and possibly leaving STEM majors and careers. The main purpose is to explore the different views women hold with regards to their environments in which they practice their field of study. Herzig's (2004b) recent study on the reasons women leave graduate mathematics provides some insight into how women view the mathematics environment at the graduate level. The women who participated in the study expressed those aspects of the environment which caused negative feelings, a desire to leave, or actually leaving the department. Poor integration into the department, family responsibilities, financial hardships, and limited or negative relationships with faculty are causes for some women to leave graduate school (Herzig, 2004b; Tinto, 1993).

There are several themes that are discussed in this section. The social and institutional characteristics are often comingled and difficult to separate because the themes are related to people and their activities in various manners. The themes that will be discussed with respect to the research are (a) nature of research, (b) advisor/faculty relationships, (c) role models, (d) others significant others, (e) department climates, (f) funding, (g) socialization of women, and (h) special status associated with studying mathematics.

Advisor/Faculty Relationships

Within graduate school, experienced students need to become successful members of two distinct communities. First is the course-taking community. Students must successfully negotiate the graduate level mathematics courses and pass qualifying exams to continue to the research stage. Often they become teaching assistants for undergraduate mathematics courses, and form bonds with future advisors. This first community represents one of the aspects of the “triple bind” discussed earlier (Etzkowitz, et al, 1994, p.43). The second community in which they must become members is the research community. The students learn to conduct research, write about the research, and form closer and tighter bonds with a small group of faculty members (Herzig, 2002, 2004a). Students’ relationships with various faculty members may be very different in each of these two communities. However, the very nature of some mathematics research leaves the students with very few people with whom they can collaborate (Earl-Novell, 2006; Herzig, 2002). Students’ relationships with faculty can last many years as scientific research and training revolve around advisors and can become very specific and highly specialized. Therefore, women’s relationships with faculty members are crucial in their success in graduate school (Etzkowitz et al, 1994; Fox, 2003). The range of experiences women have with their advisors and other faculty members varies greatly. Some women have reported belittling relationships in which the advisor made them question their self-worth; on the other hand, women have reported very supportive relationships with their advisors (Etzkowitz et al, 1994).

During the first few years of graduate study, students, particularly women, report limited relationships with faculty members (Earl-Novell, 2006; Herzig, 2004a, 2004b; Linn & Kessel, 1995). These relationships can be diverse and vary widely in terms of the quality and meaning of the relationship. Some women have reported that their relationship with advisors is limited to five minute meetings every semester for obtaining registration permission (Earl-Novell, 2006; Herzig, 2004b). Others reported that they felt professors were not interested in them as mathematics students until they passed the qualifying exams—two to three years into doctoral programs (Earl-Novell, 2006; Herzig, 2004b). Another feature that may promote professors' lack of interest in women graduate students reported by Friedman (1995) is that women who choose to pursue Master's degrees first, without applying to the doctoral program are labeled 'not serious' about doing mathematics and therefore do not receive as much attention from their advisors and the department faculty. Approaching advisors or asking faculty members to become their advisors causes female students to report high levels of anxiety as they were intimidated and scared to ask if they could work with them (Earl-Novell, 2006).

Faculty members are responsible for teaching graduate students the informal knowledge, codes and culture of the department and graduate program. In other words faculty should treat the students like junior colleagues or apprentices to the field, so that they can become accustomed to the expectations of the community (Bass, 2003; Chan, 2003; Herzig, 2004a, 2004b; Lave & Wenger, 1991; Walker et al 2008; Wenger, 1998). The students need to learn more than the mathematics discipline in order to become members of a community. This community and learn the socialization process for becoming a members.

Students should also learn about teaching and research responsibilities in mathematics, in addition to the individual roles of the faculty members (administrative and policy issues within the university and department). In order "to become mathematicians, students need to learn to *think*, *act*, and *feel* as mathematicians do" (Herzig, 2004b, p 389). The role of helping students learn about teaching and research responsibilities falls on the shoulders of the students' advisors. Through student-faculty relationships, students can gain informal and formal knowledge about the department culture and the community as a whole.

Advisors play a key role in the transmission of informal knowledge about the department and in the choices students make in their program. However, they can also be perceived as uncaring and indifferent. As a result of ineffective advising, women reported taking inappropriate classes and desiring better advising. Graduate students in general also expressed a high level of dissatisfaction with advisors in regards to their intellectual and professional growth (Earl-Novell, 2006; Herzig, 2004b, Lovitts, 2001). During the research stage of the doctoral pursuit, advisors may become more interested in their students, forming tighter bonds within the small population of colleagues and students with similar research interests. Advisor may then become role models as their students try to emulate them (Herzig, 2002; Marx & Roman, 2002).

Role Models

Starting in the seventeenth century with the Scientific Revolution women were being purposely excluded from the new practices of studying science (Sheffield, 2004). Prior to this time, scientists were those that explored the natural world using a holistic view of the world as a living organism (Sheffield, 2004). The view of world shifted during this time from a living organism to a machine, in which the point was to figure out how the machine worked and analyze all the different parts. The "new" group of scientists wanted to disassociate themselves from the old ways of doing things, and seek out universal laws in nature (Sheffield, 2004). In order to accomplish this disassociation, they systematically excluded people practicing the older views of science, including women, by forming societies and academies with limited membership. They alleged that women would "undermine their new study, in part because women tended to be followers of the old practices, but also because of the 'natural' character of women which they believed was irrational, emotional, spiritual, and lacking rigor" (pg 3). This disassociation is related to the "male model" of science today and is discussed further in the *Nature of Research*.

Etzkowitz et al (1994) state there is "two types of men in science with respect to women" (p. 47-48). There are those that follow the 'male' model of science, which has harmful consequences for women, and there are others that are conscious of the negative effects of the male model for women and attempt to avert the worst of these consequences for their women students (Etzkowitz et al, 1994). Women faculty members and students that are followers of the 'male' model of science tend to emulate their male peers and professors, respectively; occasionally these women will speak negatively about other women who do not adhere to the male model of science (Etzkowitz et al, 1994). Therefore, women in STEM have to choose from these two groups the best role models for their views of science. It is not always possible to find successful role models who are also women in STEM fields (Ferber, 2003). Since, a woman's understanding of the realm of faculty careers is influenced during their graduate school experience, it is important for them to have a steady role model that can help them in the socialization processes in graduate school and later during the student's career pursuits (Austin, 2002).

The importance of having strong role models is reported in the research (Earl-Novell, 2006; Herzig, 2002, 2004a, 2004b; Leitze, 1996; Linn & Kessel, 1996; Lips, 2007; Marx & Roman, 2002). Role models have the ability to inspire and guide women in their academic and career aspirations (Lips, 2007). Unfortunately, there often exist few positive female role models in mathematics departments (Blickenstaff, 2005; Ferber, 2003). All role models have a common feature; they appear to be competent in the area in which they are being emulated (Marx & Roman, 2002). This common attribute does not imply that all role models provide a positive representation for women of all aspects expected for exemplar faculty in STEM departments. It may suggest however, that female role models in the mathematics community may be helpful for women because these role models "represent stereo-type disconfirming evidence about women's inferior ability" in mathematics (Marx & Roman, 2002, p. 1183). Currently, because of the lack of female role models, women gain entry into the mathematics community by emulating their male role models, what Blickenstaff (2005) calls the "typical male model" (p. 376). Having strong female role models for graduate students is not only important for women graduate students; but for the men as well. Female mathematicians that are highly valued in their communities may encourage women, and give opportunities to male mathematicians to respect their female counterparts ability and knowledge (Rodd & Bartholomew, 2006).

Other Significant Persons

Besides role models, there are other people in women's lives that can have an impact on their academic and career decisions. In fact, all of society, including parents and media, is an important influencing factor on women choosing to study or not to study mathematics and other STEM subjects (Fennema, 1979). This wide variety of people influence young women's decisions, attitudes, and interests throughout their lives. During childhood and adolescence, most girls spend more time with teachers than they spend with their parents. As they get older, girls spend time with their peers and friends. Each of these groups of people plays a role in the development of the girls and young women.

Stage and Maple (1996) concluded in their study that parents play an important role in helping young women choose a major. The parental role is significant because college majors are strongly correlated with women's career choices later (Sax & Bryant, 2006). Parents reinforce women's "sense of self and view of gender appropriate behaviors" (Fox & Soller, 2001, p. 13). There is evidence that parents today are less likely to stereotype STEM majors as being masculine and are more likely to encourage their daughters to pursue those majors and careers (Fox & Soller, 2001). Interestingly, neither parent's education nor occupations appear to have an impact on women's entry into STEM fields (Peng & Jaffe, 1979).

Teachers may be the most important educational variable because of the amount of contact they have with students (Fennema, 1979). They can influence young women's beliefs about gender role standards and reinforce gender appropriate behaviors through their interactions with them and young men (Fennema, 1979). These interactions are not limited to the K-12 classroom, but also occur at the college level. Graduate women receive mixed messages from their professors. They observe statements about how important high-quality teaching is that do not agree with the ways in which their advisors spend their time (Austin, 2002). Previous professors can serve as reminders of what not to do as often as they serve as positive role models for women (Austin, 2002).

Peers can also have a considerable influence on women's educational and career choices. The peer structures on college campuses have dominated most [women's] lives (Eisenhart & Holland, 2001). The women live, work, attend class, and have more contact with these peers than their families during this time. A student's life is demanding, trying to juggle all the responsibilities involved in being away from home, personal lives and student lives. Often the juggling becomes a balancing act (Austin, 2002). The college peer culture is structured around female-male relationships (Eisenhart & Holland, 2001). This high concentration on the peer culture leads some women to struggle through school, their schoolwork was de-emphasized and peer relationships take precedence (Eisenhart & Holland, 2001; Holland & Eisenhart, 1990). Women that study graduate mathematics stated that their primary friendships were with students outside of the mathematics community (Stage & Maple, 1996). They further believed that their fellow mathematics students offered little to no support for them (Stage & Maple, 1996). Women who decide to attend graduate school in the STEM fields and are eventually successful state that encouragement from others was an essential factor in their success and decisions (Lips, 2007).

Nature of Research

Before looking specifically at the nature of mathematics research, it is important to consider the nature of doctoral programs in general. Discussions and arguments on graduate education focus on two central questions: (1) what is the doctoral degree for, and (2) who is the doctoral degree for (Walker, Golde, Jones, Bueschel, & Hutchings, 2008)? These questions are not easily answered and have been asked from the initiation of doctoral research in the United States.

Mathematics research is often perceived as a solitary act or small group act. Women expect mathematics research to be isolated and lack social interactions (Stage & Maple, 1996). One reason for the isolation is that research becomes highly focused and advanced early in the student's graduate career (Geraniou, 2010). These feelings of isolation may increase the further into the research and dissertation field on goes. "Students are left on their own with some help from their supervisor to tackle their research problem, a problem with an 'unknown' solution and no definite 'direction' towards its successful solution (Geraniou, 2010, p. 288). Other STEM subjects may not have this same sense of isolation, most science departments are run in common laboratory environments (Austin, 2002; Herzig, 2004b). However, not all aspects of mathematics are isolated. In some departments, faculty members form small specialized research groups. These groups discuss research topics and methods (Golde & Walker, 2006). However, Burton (1999) noted that calling mathematics research a solitary act is a "false stereotype , promoted by the media, of the (male) mathematician, locked away in an attic room, scribbling on his whiteboard, and, possibly solving Fermat's Last Theorem" (p 127). His research indicated that mathematicians showed a prevalence of, and a desire for researching collaboratively.

Recall the two different models of science discussed earlier, the traditional 'male' model and the 'female' model (Etzkowitz et al, 1994). In the traditional model, students are expected to have a total time commitment to pursuing their research. This model often involves aggressive competition between students, making women unsure of whom to share and discuss their research ideas (Etzkowitz et al, 1994). The other model is viewed as more of a balancing model. The people who pursue this second model, mostly women, wish to balance their personal and work environments. They try to hold more regular business hours, using the laboratory for strictly work. They also prefer to work in environments that are more cooperative and less competitive. However, types and amount of funding at both the student and professional level cause women to be more tolerable of traditional models of science (Etzkowitz et al, 1994).

While mathematics lacks the laboratory experiments and empirical data gathering that often characterize the other STEM disciplines, it still follows a traditional model of science (Herzig, 2004b). A frequent cause of doctoral women leaving a program is feelings of isolation (Becker, 1990; Herzig, 2002). This feeling of mathematics as a solitary act that might lead to isolation is a common conception often portrayed in various media outlets. For example, *A Beautiful Mind* (2001) portrayed the mathematical genius, John Nash, as being asocial, spending hours working on mathematics in isolation, either in the library or in his room, and having little regard for teaching and those in the class. Further in the book, *The Secret Life of Numbers* (Szpiro, 2006), the author describes the satisfaction a mathematician gains from completing a proof is “acknowledgement from colleagues in the same field. Experts may number no more than a dozen, spread over the farthest corners of the globe, receiving their e-mailed nods of approval often represents the height of approbation” (p. 30). It is little wonder that isolation and asocial behavior seem to permeate the stereotypes of mathematicians.

Women in mathematics doctoral programs experience discomfort in the social environment as well as the work environment. These discomforts range from women being viewed as annoying intruders to women being completely ignored (Friedman, 1995). Despite feelings of isolation and anxiety expressed by female students, many mathematics professors state that they collaborate with their colleagues and students and that is an important part of the research process (Herzig, 2004a). However, most mathematics classes are conducted in a fashion in which the instructor imparts information, the students take notes, and then go home and study the material alone (Leitze, 1996). On the other hand, Earl-Novell (2006) reported that most of the women in her study had some cooperative experiences rather than competitive ones, and these experiences may have contributed to their success within their department. A competitive environment of mathematics has been found to be “alienating, unfeminine, uncomfortable, and often distressing” for female students (Hollenshead, Younce, & Wenzel, 1994, p. 69 cited in Earl-Novell, 2006).

Further, when students provide descriptions of how they learn, they were asocial and competitive in nature (Herzig, 2004a; Leitze, 1996). Leitze (1996) found that the non-math majors in her study believed and expressed more strongly feelings that mathematics was an asocial activity. The mathematics majors in her study did not explicitly state that they felt mathematics was a solo activity, but they did express it through their descriptions of how they study and what the classroom environment was like (Leitze, 1996). These findings are not unique, many students feel this way (Herzig, 2004a, 2004b). The nature of most classrooms, where little cooperative or group work is done, may promote an environment that makes students feel isolated.

Another aspect of mathematics research is the STEM disciplines seemingly lack of connection to the world outside of the department (Stage & Maple, 1996). Women enter into majors and careers for personal and altruistic reasons more often than men (Lee, 2002). Women want to see the connections between their major or graduate research and helping people, animals or the environment.

Department Climates

Earlier, the “chilly climate” phenomenon was discussed in relation to women faculty members but the phenomenon relates to students as well. Chilly climate issues for women have been discussed since the early 1980s (see Hall & Sandler, 1982). However, the same issues related to classroom and department climates are still seen today. Some women in the sciences, including mathematics, reported that the efforts toward achievement were consistently devalued (Blickenstaff, 2005; Ferber, 2003). Department climates are shaped by the nature of the interactions between the members. Therefore, it is important for mathematics communities to encourage positive interactions and healthy relationships among their members. High levels of discrimination either gender or racial indicates a moral weakness in the community (Lovitts, 2001). Women are more likely to experience specifically gender biased behaviors from the male faculty and student body. The attrition rates for individual departments in mathematics are reported as having a large range (Earl-Novell, 2006). Large ranges of attrition rates can be a result of a department's or company's ability to integrate their members into a community of practice implying that members who are not integrated may be less likely to stay (Lovitts, 2001, Wenger, 1998).

The women in Herzig's (2004b) study reported that they felt awkward in a professional environment in which so few women participated. Hostile environments or communities toward women may arise as a result of women wishing to participate in a "process whereby young men are selected and prepared to enter an elite fraternity" (Seymour & Hewitt, 1997, p 274). Meaning women are wishing to become and are becoming members of a club (elite fraternity) that previously only had male members. As a result, club members are struggling with the changes to their fraternities. The struggles can create chilly climates or hostile environments for new members. The male environment has had impacts in other ways as well. For example in Rodd & Bartholomew's (2006) study of British students studying advanced mathematics, they found that the women would generally sit together in class, had higher attendance rates than their male peers, and their participations were lower than expected given their attendance.

Women have also described sexist behaviors they have had to endure in the STEM community. These behaviors range from unwanted sexual advances, public sexist comments, and professors who openly state that women are inferior to men, not as smart, nor as talented (Herzig, 2002, 2004a; Rodd & Bartholomew, 2006). This group of behaviors by instructors and classmates is characterized as being 'gender discomforts', which led to themes of female invisibility (Herzig, 2004b; Rodd & Bartholomew, 2006). This notion of invisibility was not only something forced on the women, but something actively sought by some women as a type of defense against the ‘micro’ and ‘macro’ inequities within a department or classroom (Herzig, 2002, 2004a; Rodd & Bartholomew, 2006; Sandler, 1999).

Funding

Students who receive funding are typically provided with more opportunities to become integrated into a department’s community. For example, students with research assistantships tend to work closely with members of the research team, frequently faculty members of the student’s own department. Research Assistants and Teaching Assistants spend time on the campus and specifically within their departments, providing them with more opportunities to interact with other students and faculty (Lovitts, 2001). Students with funding have the lowest attrition rates of graduate students; 24% and 17% respectively, compared to students with no funding; 80% attrition from their programs (Herzig, 2004a; Lovitts, 2001). Unfortunately, Vetter (1996) found that women are more likely than men to have to support themselves during their graduate study and therefore are at higher risk for attrition from their programs due to lack of funding. In fact, due to recent initiatives of the National Science Foundation there is more funding available to underrepresented minorities in STEM fields than in the past (NSF, 2010).

Sax and Bryant (2006) stated that variables related to women’s situations in college affected their career choices. “Specifically, women who expected to get a job to pay for college; receive more money from grants, family or self; and who worked part-time off-campus had higher rates of interest in traditionally female careers “(p. 60). Thus, the level of funding offered to women graduate students may highly impact their graduate school experiences and success rate.

Socialization of Women

Socialization in the STEM community is the process through which women become a member of a group (Austin, 2002). It is not something that happens over night or during occasional events, rather it is a process that continues throughout school (Austin, 2002). The acts of socialization involve learning about the culture, values, and attitudes of the people within the community (Austin, 2002). But because, graduate students are expected to work independently on their research projects; interpersonal support is rare and difficult to find in doctoral programs (Etzkowitz et al, 1994). This lack of support can amplify problems of already low levels of self-confidence in women. Research conducted by Zeldin, Britner, and Pajares (2007) states that the underrepresentation of women in STEM is a result of their self-beliefs about their capabilities in those subjects. Further, perceptions about capabilities are powerful motivators when choosing a major (Zeldin et al, 2007).

At the center of Zeldin et al.'s (2007) social cognitive perspective on women's participation in STEM are four sources of self-efficacy. *Authentic mastery experience* is the first source. If women repeatedly fail (or perceive themselves as failures) it lowers their self-efficacy beliefs. This is particularly true if those events occur early and cannot be attributed to external reasons, such as a poor assessment tool (Zeldin et al, 2007). The second source is *vicarious experiences*, or watching others perform tasks. The modeling phenomenon has the greatest effect when the role models are identified as being similar to the women observing or the modeling occurs in situations in which the observer has little experience (Zeldin et al, 2007). Social pressures or *messages from others* about one's ability in a subject are the third source of self-efficacy. Finally, *physiological indexes* are the fourth source. These indexes examine women's physical and emotional states. Powerful emotional anxiety or arousal can alter the self-efficacy beliefs of women about their capabilities (Zeldin et al, 2007). Many of these sources have connections to other reasons for women's lack of participation within the STEM community and cannot be fully separated from them.

Besides there being influences on women's self-efficacy beliefs, women and men have different patterns of socialization (Herzig, 2004a; Seymour & Hewitt, 1997). While women may develop an extrinsic sense of identity, and look to others for approval and reinforcement, men develop intrinsic senses of identity, allowing them to work autonomously and display self-sufficiency (Herzig, 2004a, Seymour & Hewitt, 1997). These traits are not consistently gender specific. Some men will exhibit extrinsic traits and some women will exhibit intrinsic traits as well. Helson (1976, cited in Becker, 1990) showed that women were just as motivated to study graduate level mathematics as men, but where the men were assertive, confident, and comfortable in their mathematics communities, the women were often the opposite -- being less assertive, lacking confidence in their abilities and feeling less comfortable in the community. These factors for women may be related to the nature of the mathematics community. Herzig et al (2006) suggested a model for integrating students into the community based on a model of apprenticeship where students are guided in becoming successful members of the student community of practice and later in the professional community of practice. This model will be discussed in more detail in a later section of the literature review.

However, not all women who excel at mathematics, computers, or science choose to pursue STEM majors and careers. It is not that they lack confidence in their skills rather they did not envision themselves in building their education or careers around such abilities (Lips, 2007). The fact that some women do not envision themselves in traditionally male careers may be related to a lack of encouragement to do so (Lips, 2007).

The Special Perception of Women in Mathematics

One theme that is present among almost all women who have been successful in studying mathematics either as undergraduates or graduate students is that they felt mathematically superior, especially in the relation to others (Becker, 1990; Herzig, 2004a; Rodd & Bartholomew, 2006). Further, students report that their interests in mathematics resulted from experiences in the early years of their education and that they were able to excel in mathematics. These factors were revealed as important for pursuing graduate level mathematics (Becker, 1990; Leitze, 1996; Rodd & Bartholomew, 2006).

The mathematics community as a field engenders, intended or not, feelings of exclusiveness among those that are able to persist in their studies (Becker, 1990; Earl-Novell, 2006). Those students that withdraw from a graduate mathematics program are seen as incapable of doing the work, failures, and people that just did not belong there in the first place (Earl-Novell, 2006). Blaming the students for their inability to finish their graduate programs for whatever reason creates a culture which allows the university or department to be free of all responsibility toward that student and places the student at fault (Earl-Novell, 2006; Lovitts, 2001; Rodd & Bartholomew, 2006).

Conclusions on University Characteristics

This section provided a brief glance at the issues and factors that influence women to leave mathematics and other STEM fields. It has explored both institutional and social factors for women's attrition from STEM majors and fields. Departmental dynamics and relationships with faculty are essential to women's participation. However, there are many reasons that women leave mathematics and other fields during graduate school. Nersad and Miller's (1996) study using data from the early 1980s found that there might be different reasons for why students leave graduate education depending on the number of years they have dedicated to study.

Many of the categories above are deeply related and cannot be separated into distinct elements. In fact, most, if not all of them would fall under the single heading of department dynamics, yet all of the categories have been researched and shown to be factors for why women may be underrepresented in the STEM fields as well as reasons for their attrition from those same fields. Some of the research described in the literature review approaches the student attrition from STEM as a "failure" of the student in some capacity. Other research, including this study, focus on looking at student attrition or success as a responsibility and partnership among members of a department (Herzig, et al, 2006; Rodd & Bartholomew, 2006). It is clear that the current philosophy of 'if enough women choose to enter the STEM fields in college and continue to STEM careers then the gender gap will be closed' is not an accurate representation of the problem (Etzkowitz et al, 2000).

Recruitment of Women in Mathematics

A consideration for recruiting women is understanding why they may leave or choose specific environments in the first place. This next section examines recommendations through recruiting and retention strategies for addressing and remediating some of the issues described in the University Characteristics and Social Influences section. Waiting for women to apply and be accepted to mathematics programs is no longer an acceptable method (Ewing, 1999). This section examines how universities and specifically mathematics departments are trying to increase their numbers in terms of women pursuing degrees at both the undergraduate and graduate levels. Also it will address some support and recruitment tactics for women faculty. Departments need to make efforts to attract underrepresented groups, including women to their programs (Ewing, 1999).

The National Research Council defined recruitment as “the interactive process, reflecting the intersection of a university’s efforts to enroll students and students’ desires to attend a particular institution” (NRC, 2006, p 14). Based on this definition the recruitment of graduate students has two factors which universities must consider. Do they try to recruit new students by using wide ranging techniques or to focus on recruiting those students which displayed an interest in their universities and departments by submitting applications for enrollment? Regardless of the recruitment technique two assumptions underlie the recruitment strategies designed to attract women to STEM. First, the group of applicants is larger than the number enrolled, and second, there are obstacles to enrolling women who are applicants but choose other institutions (NRC, 2006). No matter which type of recruitment strategies institutions or departments use, there are many markers that can set the climate and indicate the departments' commitment to and value of recruiting women (NRC, 2006).

At the graduate level, students experiences at the institution are more greatly influenced by the departments in which they choose to enroll. Therefore it is much more important for the departments to establish a climate that is women friendly and to portray it to the recruits. Department chairs can have an significant influence on the recruitment process, they can determine where the recruitment materials are sent and how it is distributed, have colleagues speak to graduate students at conferences, and have colleagues at other institutions recommend diverse candidates for graduate programs (NRC, 2006).

Both Gruenbacher et al. (2007) and Ewing (1999) found that success in recruiting women faculty and graduate students and other diverse groups involved a committed faculty member (from an under-represented group) working with the recruitment procedures. With the addition of friendly environments, supportive networks in the graduate school (Ewing, 1999) and current positive graduate student testimonials, young women can be encouraged to begin thinking about attending graduate school within the STEM disciplines.

At the faculty level, mathematics departments are receiving help in supporting and hiring new women faculty from federal agencies. One program initiated by the National Science Foundation [NSF] is POWRE: Professional Opportunities for Women in Research and Education. This program was implemented in 1997 (NSF, 2000). The goal of POWRE was to "increase participation, prominences, and influent of women …in all fields of science and engineering" (NSF, 2000, p.1). This program awarded 623 grants between 1997 and 2001 (Madsen, 2002) to non-tenured women in the sciences and engineering at critical points in their careers. However at the end of the 2001 year, the program was no longer continued, and ADVANCE (Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers) (NSF, 2008) was created to take its place (Madsen, 2002).

The ADVANCE program is also sponsored by the National Science Foundation (NSF) (National Science Foundation, 2008). The goal of this program is to develop systematic approaches to increase the number of women in science and engineering academic careers, increasing the faculty and student diversity within these programs (NSF, 2008). Since, 2006 there have been 94 awards under this program. These awards have gone to a variety of institutions both in academia and industry and range from $26,000 to $3.7 million dollars (NSF, 2008). For example, the Electrical and Computer Engineering department at Kansas State University used their ADVANCE award to sponsor a one day workshop for undergraduate women interested in pursuing graduate degrees in the STEM fields (Gruenbacher et al., 2007). Their workshop addressed five issues for the women to consider, (1) finding the right graduate school for their needs, (2) gender issues associated with graduate school and STEM fields, (3) balancing professional and personal life goals, (4) methods and strategies for success in graduate school, and (5) the application process (Gruenbacher et al., 2007).

A Framework for Studying Success of Women in Graduate Mathematics Departments

The study outlined in this dissertation is primarily grounded in the theoretical framework of learning as a social enterprise within Communities of Practice (Wenger, 1998; Wenger et al., 2002). The researcher chose the Communities of Practice lens for several reasons. First, the mathematics community has already begun to think about their programs in terms of Communities of Practice for increasing their diversity and the number of US citizen enrolled in them (Golde & Walker, 2006; Herzig et al., 2006). Second, if the community of practice framework is successful at the highest level of education in recruiting women and helping them to graduate successfully, then it may also benefit K-12 education as well.

Communities of Practice

Humans are by their very nature highly social beings and therefore learning can be thought of as a social phenomenon (Wenger, 1998). Vygotsky expounded on the ideas that education should be based on principles that the learner is part of a society and that learning is a social activity (Langford, 2005). If one believes this, then the learner is expected to acquire their needs and interest from society and pursuing them will have a beneficial influence on the learner and society. Each learner constructs their own social reality from their perceptions and knowledge of the society in which they live (Anderson, 2007; Bickard, 2004; Langford, 2005).

If learning is a social activity, then knowledge is constructed through social interaction and participation within communities, and learning occurs through experiences and practice (Wenger, 1998). Every person belongs to a variety of "communities of practice." For example, a student may belong to their family community, school community, athletic community, and a peer community. Each of these communities may have different expectations for behavior and roles of the participants. With time, the different communities to which a person may belong can change. When a person changes or becomes a member of a new community of practice they must negotiate the new environment and learn to participate with competence (Wenger, 1998). Participation within these communities may have a variety of meanings. Individuals must learn to engage and contribute to the community; communities themselves need to refine their practices and recruit new members. The individuals may exhibit different levels of participation in their communities. They may be "core" members and deeply entrenched within the community, for example full-time graduate students tend to be core members of their community because their level of involvement is essential to their success. Alternatively, an individual may only be a peripheral member of a community, meaning they are minimally involved (Wenger, 1998). An example of a peripheral member might be a graduate student who lives further than 60 miles from the campus, attends one class a semester and is not involved with the university department in other ways.

Membership in Communities of Practice is not only about participation. It is more than apprenticeship and indoctrination, but "a matter of linking layers and realms of experiences with the initial questions of membership" (Star, 1998). These questions of membership may be 'do I belong in this community? What do I know about the community already? Do I have the proper background? How do I get the necessary background?" Each of these questions is answered through a member's participation and experiences in the community and helps them to apprentice the field.

There are three basic components of a Community of Practice: domain, community, and practice (Wenger et al., 2002). See Figure 1. In the very center where the three elements all overlap is considered the Community of Practice. The Domain is the common ground and a sense of common identity that a group shares. Community is the social structure of learning. Finally, Practice is the shared set of frameworks, knowledge, resources and tools (Wenger, et al., 2002). All three of these tenets need to be developed in parallel and are dynamic, such that new practices arise and old ones are thrown out (Wenger, et al., 2002).

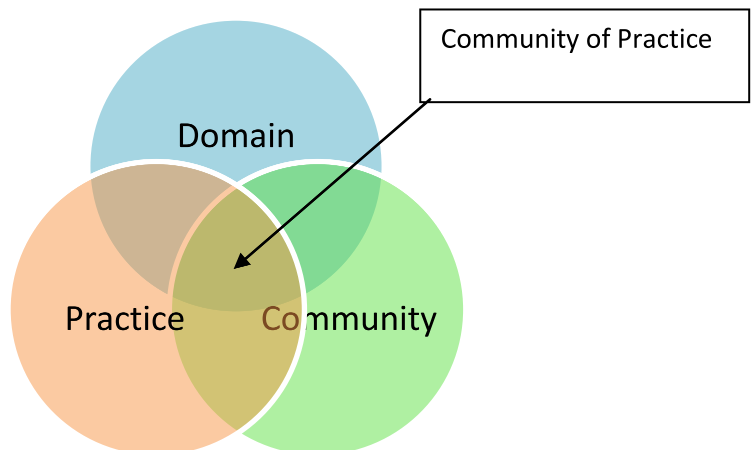

Figure 1: Relationship between Elements of a Community of Practice

Domain is described as the common ground and sense of identity of the participating members. It inspires members to participate in the community, contribute relevant information, and gives a sense of accountability to a body of knowledge and therefore the development of a practice (Wenger et al., 2002). Domain is not some abstract notion. It is comprised of key issues or quandaries that participants experience (Wenger et al 2002). These experiences help create a sense of member identity through their familiarity with the issues or problems involved. These issues are not passing fancies, but rather are complex and have long histories within their specific domains that require substantial learning by the members (Wenger et al., 2002). For example, a university mathematics community is interested in how to prepare graduate students for different careers; this is common domain.

The graduate mathematics department domain is not a fixed set of problems, but is dynamically evolving with the community. A successful Community of Practice is one where the domain connects the goals and needs of the community with the passions and aspirations of the members (Wenger et al., 2002).

Practice is the socially defined, specific knowledge, the community develops, shares, and maintains such that the community operates as a living curriculum (Wenger et al., 2002). This knowledge includes frameworks, tools, information, styles, languages, and symbols. The purpose of practice in this framework is to share this knowledge with other members in order for them to work together effectively and efficiently as well as to explore advances in existing knowledge and in orienting that knowledge toward the future (Wenger et al., 2002).

Students must learn *and* create mathematics content (Herzig et al., 2006). Within a university, all doctorate students must gain and demonstrate this knowledge through the dissertation or thesis process to graduate. For instance, in a mathematics community of practice, the graduate students are expected to complete required coursework and become knowledgeable in specific mathematics areas. To demonstrate their knowledge, the students must pass a qualifying exam. However, simply knowing the basic content is not enough; members need to learn and explore the latest advances in the field (Wenger et al., 2002). A body of shared knowledge and resources allows a group of people to communicate effectively. Practice is not simply limited to content knowledge; it also encompasses knowing the history of the community (Wenger et al., 2002).

Community is described as the social fabric of learning and is essential to a successful and efficient knowledge structure (Wenger et al., 2002). Members work together toward a common design of how the community should appear; building trust and lasting relationships along the way (Wenger, et al., 2002). Further, by working together, the members of the community can remove barriers to relationships through directly addressing issues and problems in the working environment. Within this community and relationship based environment, members are comfortable enough to use each other as sounding boards for ideas, build on each other's ideas without fear of criticism, ask for help, and interact regularly on problems and issues within the domain (Wenger et al., 2002).

By choosing the Communities of Practice Framework as a theoretical lens, the researcher hypothesizes that the successful graduate mathematics departments she studies may operate as Community of Practices. Thus she uses "Communities of Practice" as a theoretical lens for developing the research agenda, creating instruments for collecting data, analyzing data, and reporting results. Communities of Practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger, et al., 2002, p. 4). Based on this definition it is reasonable to imagine that a mathematics department within a university is a community of practice and that a larger community of practice could possibly consists of mathematics departments in all universities. By examining the practices within these departments and linking those practices to students' perceptions and experiences within the mathematics departments, the researcher hopes to discover successful practices for graduating women doctorates in mathematics.

Communities of Practice and Research in Mathematics Education

Some research in mathematics and science education embraces the ideas and tenets of the Communities of Practice in a specific content field such as mathematics (Stein, Silver, & Smith, 1998; Star, 1998). Within the last twenty years there has been a shift in mathematics education from instruction in teacher-centered classrooms where students are passive learners to student-centered classrooms where both the teacher and the students take an active role in their learning of mathematics. This movement has been spurred by the National Council of Teachers of Mathematics (NCTM). In their Professional Standards (1991), NCTM outlines a learning environment in which the focus is on building "intellectual communities" in the mathematics classroom:

> *This standard focuses on key dimensions of a learning environment in which serious mathematical thinking can take place: a genuine respect for others' ideas, a valuing of reason and sense-making, pacing and timing that allow students to puzzle and to think, and the forging of a social and intellectual community. Such a learning environment should help all students believe in themselves as successful mathematical thinkers* (NCTM, 1991, Teaching Standard 5).

Nine years later, NCTM published the Principles and Standards for School Mathematics (2000). This document was created as a "comprehensive and coherent set of learning goals that orient curricular teaching, and assessment efforts for the PreK-12 mathematics in the United States, it is a resource for teachers, leaders and policy makers to use in examining and improving instructional programs in mathematics" (NCTM, 2000). One can argue that the principles and standards set forth an outline of changing the classroom environment, so that all students have the possibility of being successful in mathematics.

The NCTM does not make direct references to the Communities of Practice (Lave &

Wenger, 1991; Wenger, 1998). However, some of the same ideas are connected within both the theory of a community of practice and the *Principles and Standards.* For example, both ideas want students to have a shared body of knowledge created through discourse, problem solving, and communication. Discourse and communication are linked with the foundation of community in Wenger's Community of Practice framework, while problem solving is connected to the practice. Students will need to learn what problems are relevant, how to solve them and how to communicate their findings.

There is a historical precedent for using a focus on communities as a frame for this study. Past studies in mathematics education have set the stage by examining the different elements of domain, practice, and community through the use of different frameworks and lenses to study classroom, students, and teacher education research (see Eccles & Jacobs 1986; Nickson, 1992; Philipp, 2007). Some research in mathematics education has also explicitly used the ideas associated with the Communities of Practice (Kanes & Lerman, 2008).

Domain as the common identity of the group, and how members situate themselves within the community has been studied in mathematics education, through research concerning attitudes (Aiken 1976; Farooq & Shah, 2008; Eccles & Jacobs 1986; Fennema & Sherman 1976), beliefs (Philipp, 2007; Thompson, 1992), and self-efficacy of students (Hackett & Betz, 1989; Pajares & Graham, 1999). Research on students' attitude toward mathematics has value in considering the domain because they reflect how the students situate themselves in mathematics communities in which they take part. Each of these three areas provides insight into how students perceive themselves in the mathematics community and that perception affects their participation.

Aiken (1976) wrote a synthesis of the research published between 1970 and 1975 on attitudes as a variable for learning mathematics. He separated the research by grade level, student attitudes, teacher attitudes and other factors affecting attitude. Within each of these areas, he gives a synopsis of the literature and the appropriate references. Fennema and Sherman (1976) published an instrument designed to measure student attitudes toward the learning of mathematics. A quick Google scholar search shows that their article is still being adapted for current studies (see Liau, Kassim, & Loke, 2007). This connection reveals that student attitudes toward mathematics are still important to the mathematics education field and can contribute the success of students in mathematics. However, student beliefs may be rooted in the classroom experiences of the students.

In addition to attitudes students come to the mathematics classroom with “baggage” which is multi-dimensional and helps the student to form a mathematics identity (Eaton & O’Reilly, 2009). Mathematical identity is a term that is used to describe the complex relationship that a student has with mathematics. This relationship is situated within their experiences, perceptions of those experiences, themselves, and others (Eaton & O’Reilly, 2009; Wenger 1998). At the graduate level, students may have similar mathematics’ identities that lead to their easy enculturation into a Community of Practice.

Practice, or the knowledge that is shared by the Community of Practice, has been situated within studies about curriculum implementation and reform, because curriculum dictates what students are expected to learn. Research related to practice can also be found in how students learn mathematics (see Second Handbook of Research on Mathematics Teaching and Learning, 2007), and teacher practice (Franke, Kazemi, & Battey, 2007, Koehler, & Grouws, 1992). While each of these kinds of studies lead to understanding what mathematics is, what types of mathematics are valued, and how that knowledge is conveyed to new students, they are not typically situated within the Communities of Practice framework. Instead, researchers use other types of framework and theoretical lenses. For example several studies have examined how mathematics is taught in the K-12 education system and it's relation to student learning. One strand of research that addresses curriculum and K-12 mathematics is centered on Cognitively Guided Instruction (CGI) (Carpenter, Fennema, & Franke, 1996). CGI focuses on "children's understanding of specific mathematical concepts [and] can provide the basis for teachers to develop their [students'] knowledge more broadly" (Carpenter et al., 1996, p4). The relationship between CGI and practice lies in understanding how teachers construct their own understanding of what students knows and how that influences their instruction. Using a CGI based curriculum allows teachers use student understanding to guide their knowledge of pedagogy, content, and curriculum (Carpenter et al., 1996). This in turn influences their classroom practices.

At the post-secondary level, Burton (1999) used the Community of Practice ideas from Lave and Wenger (1991) to examine the practices of mathematicians and what those practices mean (1999). In his interviewing of 70 mathematicians, he outlined their beliefs about the benefits of their mathematical communities. A major finding as a result of the Burton study is that the "cultural climate in which mathematics is researched has shifted from a predominantly individualistic to a predominantly collaborative/co-operative one" (p 137).

This raises the question then, why are not more mathematics classrooms, programs, and curricula making the shift?

Not only should teachers and researchers help students become co-operative problem solvers, but mathematics teachers should collaborate with peers and mathematicians for improving mathematics education. In mathematics education, the National Council of Teachers of Mathematics (2000) urges collaboration among many different groups, advocating for such a change. First, mathematics teachers should collaborate on problems centered on teaching mathematics, through visitations, critiques, and discussions based on their experiences. Second, students become problem solvers in both groups and alone. Third, researchers and teacher educators should collaborate with classroom mathematics teachers to "investigate research questions based in classroom practice or to look at mathematics as it occurs in classroom" (NCTM, 2000, p 377). These types of collaborations can lead to the building of communities at various different levels. For example, university researchers and classroom teachers working together to improve mathematics education may create a community in which they meet regularly to discuss lesson plans, analyze student work, and create lessons for the future (NCTM, 2000). However, these communities should also extend to include the students. Teachers should support classrooms where students have opportunities to test and share ideas based on the knowledge of mathematical community in which they participate and feel free to express their ideas for the community to consider (NCTM, 2000).

Building these communities in the classroom leads to discovering what community is. Finally, community, the social fabric of learning, has been researched in mathematics education in many studies. These studies include investigations into the socio-mathematical norms of a classroom (Yackel & Cobb, 1996), and a culture of a classroom (Nickson, 1992; Nunes 1992; Presmeg, 2007). When thinking about a classroom culture, or environment, care must be taken to not assume that there is only one such culture or that only one type of environment is desirable. Mathematics pedagogy and thinking have evolved into two traditions. The first tradition has been in used for a long time; while the second tradition, has more recently come into practice (Nickson, 1992). The first tradition is created on the basis that mathematics is not influenced by human experience and that it is a series of immutable truths and unquestionable certainty and that the foundations of mathematical knowledge are beyond human action (Nickson, 1992). The second tradition is more grounded in the social aspects of what it means to do mathematics. This movement can be seen in both the National Curriculum Council (1989) in the United Kingdom (Nickson, 1992) and in the NCTM publications related to the principles and standards (2000).

Other studies are connected to the Communities of Practice framework in more than one dimension. Yackel and Cobb (1996) focus on norms in the classroom. Their research focuses on building classroom environments which contribute to mathematical conceptual development (community and practice) and examine how these environments impact student beliefs and attitudes (domain). Further, the *sociomathematical* norms that Yackel and Cobb focus are different from classroom norms. Sociomathematical norms are specific to mathematical activity and learning (1996).

This brief synthesis on research in Mathematics Education shows that there is a precedent for using the elements important in the Communities of Practice framework for examining mathematical work of teachers and students at a classroom level. The following section examines an enterprise at the graduate level that incorporates the Communities of Practice ideas into the goals for doctoral programs.

Carnegie Initiative on the Doctorate

At the graduate level of education, one organization that has taken an interest in the socialization process of doctorate students, particularly women, is the Carnegie Foundation. The Carnegie Initiative on the Doctorate (CID) is a "multiyear research and action project to support departments' efforts to more purposefully align the purpose and practices of their doctoral programs" (Carnegie Foundation, 2006). Walker (2004) draws attention to issues that have existed for decades in improving doctorate studies in the United States. Some of these concerns are issues for women in attaining graduate degrees in the STEM areas. For example, diversity with programs, quality and structuring of mentoring programs within departments, amount of time spent obtaining a degree, and interdisciplinary and multidisciplinary opportunities have been known and the topics of deliberations since the 1950s (Walker, 2004).

During the last few years, discussions about the state of doctoral programs in a variety of fields have been taking place (Golde & Walker, 2006). These discussions have focused on what it means to pursue a doctorate in terms of students learning both content and professionalism related to their specific fields. Leading the way in the discussions is the idea of a "steward of the discipline" (Golde, 2006, p. 9). A "steward of the discipline" is a phrase used to describe two major roles for graduate students. First, the students must know the content of the field in which they are studying, and second, the students have an obligation to pass that knowledge to others.

As a result of this discussion, several articles have been written stimulating conversation among mathematics departments across the country. In one such article, Bass (2003) explores the shifting nature of the meaning of mathematics as well as the purpose of doctoral programs within mathematics departments. His discussion embraces the subject of mathematics as a discipline versus mathematics as a profession and the effects of this difference on different student groups. Mathematics as a discipline is concerned with content knowledge and furthering mathematics research. Mathematics as profession encompasses a much larger idea; that knowledge generation, application, conservation, and transmission as well as the interaction with other areas of study and universities within the larger society of academia (Bass, 2006). Further, Bass claims that doctoral programs should be designed to create a sense of cultural awareness of mathematics and its significance in the larger world of science and society (Bass, 2003).

This cultural awareness of mathematics and its significance is a relatively new area to be considered for doctoral programs in mathematics. In the past, "the doctoral program in mathematics was designed to be an apprenticeship into the research practice of an academic research mathematician" (Bass, 2006, p. 107). However, this model is not appropriate for all students. Academic institutions are the biggest employers of PhDs in mathematics, although not all of those jobs are tenure-track. In addition, almost one third of students take jobs outside of academia (Golde & Walker, 2006). The number of jobs in academia differs from year to year depending on budgetary issues, and a lack of positions. Therefore, students that enter programs now demand career preparation in areas other than academia as well as the skills and content knowledge necessary to become scholars in the field (Chan, 2006).

Understanding and knowing the practices, expectations, and one's expected role in a community of practice eases one's entry into that community. Much of the knowledge about and within such communities is informal. Therefore, the information needs to be transferred by existing members to new members (Bass, 2003; Chan, 2003; Herzig, et al., 2006; Wenger, 1998). Currently the American Institute of Mathematics (AIM) is working on recruiting to and retaining students in the mathematical sciences community. They are focusing on working to support students as learners using Lave and Wenger's (1991) model of apprenticeship (Herzig, et al., 2006). Their focus is to support the students in three dimensions, which are important in the training of apprentices: "(1) helping students learn and create mathematical content, (2) helping students learn the practices of mathematics, (3) and helping students develop identities as members of a mathematical community" (Herzig, et al., 2006, p. 4). The purpose of a Community of Practice "to create, expand, and exchange knowledge, and to develop individual capabilities" (Wenger, et al., 2002, p. 42) correlates well with the goals of the AIM's workshop (Herzig et al, 2006) and the Carnegie Initiative of the Doctorate (Golde & Walker, 2006).

Focus on Current Research

Blickenstaff (2005) states that the focus of university STEM departments for bringing together women and STEM encompasses three aspects: (1) recruiting women to the field (2) retaining the women that are recruited, and (3) changing the nature of STEM fields to be more inclusive of women. These thoughts are echoed within mathematics departments through the Carnegie Initiative (Bass, 2003; Chan, 2003; Jackson, 2004a). The retention of women and minorities in graduate mathematics programs is the entire community's responsibility (Tinto, 1993). Not all universities or departments do a poor job of integrating their students in the mathematics community as many universities and departments are making efforts to increase their diversity through participation in workshops. Eight universities took part in the American Mathematical Societies 2006 workshop on "Finding and Keeping Graduate Students in the Mathematical Sciences" (Herzig et al, 2006) and three of these universities are among the leading mathematics departments granting doctorates to women (Jackson, 2004a).

Women are earning mathematics doctorates in large numbers at some universities; this implies that women have the ability to be successful in graduate mathematics programs and are not lacking some essential gene. Further, it places responsibility on the universities and the mathematical communities for recruiting and retaining women. Part of this responsibility is making sure that students have safe bias free environments in which to learn and grow as a part of the community. The issues surrounding women in graduate level mathematics have been reported over two decades. While individual universities have sought ways to retain their women graduate students, the problem of high attrition rates are still valid but perhaps not as universal as they once were. Research into why some departments are successful at producing at high percentage of women mathematicians may be a method for gaining insight into which elements of the community can be successfully negotiated by the participants and are contributing to that success.

The next chapter discusses the research design, how the framework connections to the design and each of the different phases of the study.

CHAPTER 3: METHODS

The goal of this study is to explore and describe successful practices utilized by doctoral granting Mathematics Departments, through an analysis of both graduate students' and faculty members' perceptions of their respective mathematics departments and graduate programs. The study describes the characteristics of mathematics graduate programs that have been successful in producing a comparatively higher percentage of women with mathematics doctorates. One way to approach this problem is through a case study research design (Stake, 1994; Yin, 2009). The case study methodology will allow the researcher to examine a University Mathematics Department (UMD) as the collective unit of analysis.

The researcher chose to use a collective case study design using six broad cases and one in-depth case (Stake, 2005; Tellis, 1997b). A collective case study is a "number of case studies that may be studied jointly in order to investigate a phenomenon, population, or general condition" (Stake, 2005, p. 445). The common element in these six cases is that each of the mathematics departments graduates relatively large percentages of women doctorates. Percentages of women doctorates are consider "large" in relation to the percentages that are more typical across most mathematics departments.

This chapter first outlines the framework used for framing and analyzing the study and then presents the complete research design of the study. The research design is broken down into four major parts, Phase 0, Phase I, Phase II, and Phase III. Within each of the phases; participants, data collection, and data analysis are discussed. The chapter concludes with a discussion about the validity and reliability of the study.

Framework

The "Community of Practice" as defined by Wenger et al. (2002), and discussed in Chapter 2, is the theoretical lens for this study. Communities of Practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger, et al., 2002, p. 4). In addition to the Communities of Practice framework, the literature on women's participation in STEM provided yet another layer for looking at why women choose to participate in specific environments and are successful within a university mathematics department in this collective case study. This section explores the Communities of Practice framework in more detail through the three elements; domain, practice, and community.

The *domain* of a Community of Practice is whatever creates the common ground of the members and defines the identity of the community (Wenger et al., 2002). The domain inspires members to participate in the community, contribute relevant information, and gives a sense of accountability to a body of knowledge and therefore the development of a practice (Wenger et al., 2002). This common ground consists of key issues or problems and guiding questions and provides an organization of knowledge (Wenger et al., 2002). The study was designed in a manner so that the researcher may be able to clarify what the needs of community are and how those connect to the aspirations of the members.

Practice is the socially defined ways of doing things within the community; these include frameworks, ideas, tools, information, styles, languages, stories, and documents

(Wenger, et al., 2002). The literature on the purpose of the mathematics doctorate has used the ideas of practice in their quest for improving the doctorate experience for students.

Community is the social fabric of learning; it is the interactions and relationships based on mutual respect and trust among community members (Wenger, 1998; Wenger et al., 2002). Members need to be willing to share new ideas, expose their weaknesses, ask difficult questions of other members, both content and practice oriented, and to listen carefully to the ideas and questions of others (Wenger et al., 2002). Herzig et al (2006) calls this learning to practice mathematics in a university mathematics department. Figure 2 shows all three elements of the Community of Practice and how they are related. According to Wenger et al (2002) a Community of Practice is when all three of the elements are working together, shown as the intersection area of the three circles.

Membership within a community of practice is voluntary; one cannot be forced into participation (Wenger et al., 2002). Women are choosing to become members of the 6 university mathematics departments in this study. Some of the reasons for community members to participate are (1) because they care about the domain, (2) want to interact with peers, (3) want to make a contribution that is genuinely appreciated, and (4) to learn the practice (Wenger et al., 2002). While all three of the elements, domain, practice, and community, need to be present to have a "Community of Practice" as defined by Wenger (1998), women may be drawn to mathematics departments that currently only embody one or two of the elements. Not all mathematics departments are necessarily going to be complete Communities of Practice, but they may employ specific elements of a community practice. It is also possible that some successful mathematics departments are not Communities of

Practice at all or have several Communities of Practice operating within them rather than one large one.

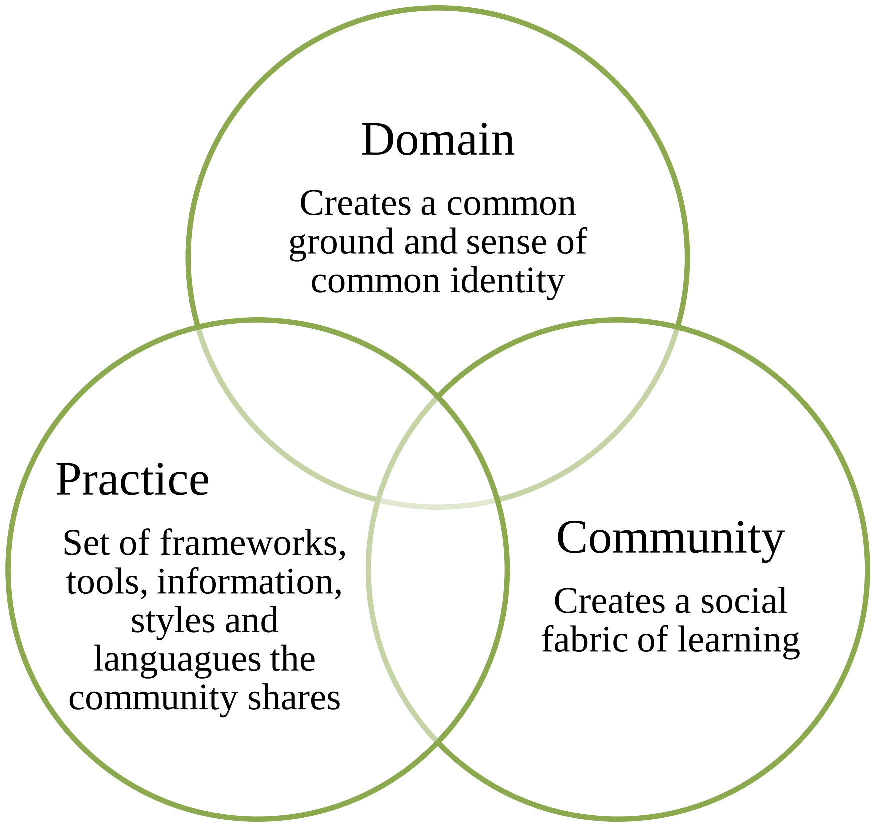

Figure 2: Outline of the Community of Practice Framework
(Adapted from Wenger et al, 2002)

Research Design

Overview of the Study

The researcher divided the study into four phases. The researcher designed each phase to examine a different perspective of the University Mathematics Departments (UMD). Phase 0 provided an initial look at the six mathematics departments through their websites using a rubric developed by the researcher. Phase 1 helped establish the recruiting policies of the universities, and provide the DGP's perspective of the mathematics department. Phase 2 of the study examined the graduate students' perspectives through factors they considered in choosing a graduate program. The final phase, Phase 3 allowed the researcher an in-depth look at one UMD through a site visit to immerse the researcher in the community that included a new student survey and an examination of both doctoral student and faculty members' perspectives through interviews. Throughout all the phases, the researcher looked for elements of the Community of Practice framework and how they related specifically to mathematics through the literature on women's experiences. The selection of universities for Phase 3 was based on the document collection and survey results from the first and second phases. Table 3provides an overview of the participants and data collected in each phase of the study. First is a discussion of the IRB Permission, the recruitment of university participants, and the university participants in the study. Second, each of the four Phases will be discussed in more detail. Within each phase, sampling, participants, data collection, and data processing are discussed. Data analysis is discussed after the four phases and in relation to the three research questions.

Table 3
Overview of the Research Design

Phase 0						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	Website Evaluation of Mathematics Department and their graduate program websites					
Total Participants	6 Mathematics Departments					
Phase I						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	DGP Phone Interview Document Collection					
Total Participants	6 Mathematics Departments 6 DGP Phone (or face-to-face) Interviews					
Phase II						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	Graduate Student Online Questionnaire					
Total Participants	150 graduate students Student participants from all 6 universities					
Phase III						
In-depth Case Study Participants	Preston					
Data Collection	Faculty Interviews Graduate Student Interviews New Student Survey					
Total Participants	12 Faculty Interviews 17 Student Interviews 5 New Student Survey Responses					

IRB Permission

The researcher completed an application to conduct research with human participants with the university's Institutional Review Board and received approval to conduct the study (IRB number: 317-08-10). All participants, UMDs, graduate students, and faculty members were guaranteed anonymity if they agree to participate. A Director of Graduate Programs (DGP) or the administrative equivalent represented each UMD and agreed to aid the researcher in data collection from his or hers particular university. This representative participated in a phone (or face-to-face) interview, and sent emails to the graduate students soliciting their participation in the online questionnaire. All DGP participants read and signed an informed consent form (See Appendix A for consent forms for all three phases). Also, the UMDs were given the option to participate in only part of the research without penalty and participate in only those phases they wished. Outlined below are the options UMDs had for participation for Phases I and II.

(1) Grant access to internal documents pertaining to graduate student recruiting and retention
(2) Participate in a phone interview lasting 30-45 minutes
(3) Aid in the solicitation of volunteers to complete the graduate student online questionnaire
(4) Add questions to the graduate student online questionnaire
(5) Receive aggregate data from the graduate student online questionnaire
(6) Express willingness to participate, if chosen, in Phase III of the study

To ensure anonymity, the researcher referred to all participants using an alpha-numeric code for the data analysis, and a pseudonym in the writing of the results. This code prevented participants, both universities and individuals from being identifiable in the written report. One year after the completion of all data analysis, the data will be destroyed.

Recruitment of University Participants

The University Mathematics Departments (UMD) chosen as possible participants were selected using a purposeful sampling (Creswell & Clark, 2007). The following criteria were used to select the departments:

- Doctoral granting institutions
- Relatively large percentage of mathematics doctoral graduates is women.

First, a pool of possible participant mathematics departments was created through an examination of recent graduation records, research publications and web sites that specifically address women in mathematics (such as American Association of University Women, Association for Women in Mathematics and Women in Engineering: Program Advocates Network, See Appendix B for a list of URLs). Jackson (1991, 2004a) reported two sets of data related to the number of women doctorates awarded. The first set of data released in 1991 focused on the ten year period between 1980-81 and 1989-1990, while the second set of data focused on the academic years 1995-1996 to 2002-2003. These reports are based on the Annual American Mathematics Society-Mathematical Association of America Surveys. Appendix C shows the universities that produce the highest percentage of women mathematics doctorates for both studies (universities highlighted in purple appeared on both lists).

Another source was the American Institute of Mathematics (AIM) 2006 workshop on "Finding and Keeping Graduate Students in the Mathematical Sciences" (Herzig et al, 2006). The workshop directors brought together 14 leaders from the university mathematics departments (see Appendix D), in order to provide support and motivation for recruiting and retaining women graduate students (Herzig et al, 2006). Workshop participants created written plans for increasing recruiting efforts and supporting women students within the departments. These two sources along with the Graduate-Schools.phds.org ranking of the top universities producing 43% or better graduate degree earning women (Appendix E) helped create the initial list of possible university participants. Ultimately, a total of twenty five University Mathematics Departments were invited to participate in this study, with a plan to elicit participation from about 15 UMDs.

University Participants

The twenty-five University Mathematics Departments (Appendix F) were originally contacted through email to the Director of Graduate Programs (DGPs) by an official letter of invitation (Appendix G), with a print letter following in the mail. Those DGPs who responded were sent further information and a dialogue ensued concerning the study. Of the twenty-five invited UMDs, six UMDs agreed to participate in the study, instead of the proposed fifteen. Table 4 outlines each of these participants. The UMDs are listed in the order in which the Graduate Student Online Questionnaire (see Phase II) was completed.

Table 4
Participating University Mathematics Departments

UMD	Location (See Region Map Appendix H)	Number of Graduate Students in Department [a]	Number of Faculty in Department [a]	Degrees Offered [a]	Graduate Program Description [b]
Preston University	Public Southeast	≈200	≈60	B.S. in Math, Applied Math, Math with Concentration in Financial Math M.S. in Math or Applied Math Ph.D. in Math, Applied Math, Interdisciplinary Math	Doctoral, STEM Dominant
Baldwin University	Public West	≈100	≈30	B.S. in Pure, Applied Math, Education Math, Computation Math, or Statistics, M.S. or Ph.D. in Pure Math, Applied Math, and Applied Statistics	Comprehensive Doctoral, with Medical and Veterinary
Caldwell University	Private Northeast	≈20	≈20	B.A. and M.A in math and computer science, interdepartmental major in math and economics Ph.D. in math	Doctoral, STEM Dominant
Weston University	Private Southeast	≈40	≈30	B.A. or B.S. in Math, Ph.D. in Math or Applied Math (M.A. earned at completion of 30 hours and passing qualification exams)	Comprehensive Doctoral, with Medical and Veterinary
Wagner University	Public West	≈60	≈30	B.A. in Mathematics, M.A. in Mathematics, M.S. in Applied Math, Ph.D. in Math	Comprehensive Doctoral, with NO Medical and Veterinary
Chelsea University	Public Central	≈200	≈60	Majors in Math, Actuarial Science, Math & Computer Science, Statistics M.S. in Math, Applied Math, Teaching of Math Ph.D. in Math	Comprehensive Doctoral, with Medical and Veterinary

Notes: The following superscripts indicate where the data was collected.

a. Based on data collected from the Universities Respective Websites
b. According to the Carnegie Foundation at http://www.carnegiefoundation.org/classifications/index.asp?key=807

Each of the following sections will describe the four phases of the study, including participants, instruments and data collection, and data processing.

Phase 0

The initial phase of the study involved an examination of the UMDs' websites (Table 5). These evaluations provided the researcher with firsthand knowledge about the different types of information on the website, how the site is organized and what role that site plays in recruiting new students through their perspective student pages. This perspective was important to the study because the website is often the "public face" of the department and the first place that prospective students look for information about graduate programs (Burack & Franks, 2006). The department website provides information to prospective students and faculty (as well as current students and faculty) concerning what the department considers to be domain, practice and community. For example, if a website lists the qualifying exam requirements doctoral students must complete in order to graduate, the department is stating something about what it believes to be practice. In other words the qualifying exams demonstrate the content knowledge the students need to learn. An example of the domain for the UMD would be found in a description of the mathematics department, or a mission statement for the department. A description could include what the department sees as valuable and what they expect students to contribute to the group's identity.

Table 5: Phase 0 Outline

Phase 0						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	Website Evaluation of Mathematics Department and their graduate program websites					
Total Participants	6 Mathematics Departments					

Instruments and Data Collection

The evaluation of the department's websites was grounded in a rubric created by the researcher using the research literature. The rubric explores five dimensions of each website. The first dimension is the "Welcoming" aspect of the website. A website is considered welcoming if it includes quality pictures, accurate and up-to-date information, links to other helpful websites, current news and events, and bulleted, easy to find links (Burack & Franke, 2006; Gorski, 1999; Montelone, Dyer, Burack, & Franks 2006). A second dimension the rubric focuses on is the navigability of the websites. Websites need to be easy to navigate and should be designed in such a manner that users can easily find necessary information. This means that links should be functional, contact information is available, and there is convenient access to departmental information (Gorski, 1999; Montelone et al, 2006). Websites that are not easy for users to navigate can cause the user to disengage, and look for information elsewhere. It may even turn prospective students away from good departments that may not have well designed and navigable websites (Gorski, 1999). The third dimension the rubric focuses on is inclusion, or the educational-aesthetic issues (Burack & Franke, 2006). This dimensions examines the relevancy and accuracy of the material posted, does this material meet both graduate student and faculty needs, and does the website provide diversity friendly links, either to internal or external organizations. The fourth dimension examines how the website purveys information about the department's aspirations for linking diversity to the purpose of the department (Burack & Franke, 2006). It also examines how the department characterizes their students as professions through images and recognition of achievements. The final dimension determines if the Mission Statement and Diversity Statements are explicitly stated and convey the goals of the department (Gorski, 1999).

In Phase 0, the six UMDs' websites were examined and evaluated. The website evaluation was used to help characterize the six departments with respect to the information they provide for the public domain. Also, the websites were used as secondary data sources in terms of information about the departments and to gather more formal knowledge on Phase II participants' responses.

Table 6 shows each of the five aspects of the website evaluation rubric, their elements, and descriptors for each of the elements. The table notes denote the sources used for each of the elements and descriptors. Appendix I is the rubric as presented and used by the evaluator(s) and Appendix J is the tool the evaluators completed.

Each UMD's website was examined for specific information related to content in the rubric. However, evaluators were specifically asked to look at specific pages (if they existed) within each UMD. Within each page, the evaluator was instructed to read the information and consider both the rubric, and their general feeling toward the website. Therefore, the evaluation was two-fold. In considering the rubric, the evaluator tried to view the website in an unbiased way. At the end, the evaluator thought about their overall impression of the website, and whether or not they would return to that site in the future.

The first page viewed was the home page for the entire department. This was chosen for two reasons. First, it is the page that people are first directed too, either through a Google type search or through the university's directory of academic departments. Second, the UMD's homepage provided links to other pages concerning programs, degree qualifications, people in the department, etc. The second page evaluators examined was the graduate program page. This page often described the different graduate degrees and programs within the UMD. Evaluators also looked at the prospective graduate students' page. This allowed the evaluators to look at web pages in which the purpose may include recruiting students. Next, the people of the department pages were viewed. This gave the evaluators a sense of diversity within the department (if pictures were provided). Evaluators then spent the rest of the evaluation following different links and looking at pages that might be specific to particular UMDs. It is important to note that undergraduate program pages or pages on other types of programs within the department, such as statistics or computer science were not viewed in this data collection.

The rubric was pilot tested using six UMD websites different from those in the study. These six departments were randomly selected. The pilot study was conducted by the researcher and an external evaluator to ensure the use-ability of the rubric and the clearness of the terms and scoring. After the completion of the Pilot Study, changes were made to the directions for the rubric, outlining which pages the evaluators were specifically to view.

Table 6
Website Evaluation Rubric

	Element	Descriptors
1. Welcome[2]	1.1Color and Font [a]	1.1.1 Easy to read [a, b] 1.1.2 Background does not interfere with the text [b, c] 1.1.3 Consistent design/style gives the site coherence 1.1.4 Minimal clutter [b]
	1.2 Language [a]	1.2.1 Avoids generic masculine pronouns [a] 1.2.2 Uses active rather than passive voice (80% of the time) [a] 1.2.3 Uses everyday language to convey goals [a]
	1.3 Pictures [a, b]	1.3.1 Photos include students interacting with faculty in classrooms and labs [b] 1.3.2 Uses images that humanize the site and make it more aesthetically attractive [a] 1.3.3 Include images of women and minorities in positions of leadership [a, b]
	1.4 Well Organized and Functional [b]	1.4.1 Easily located information [b] 1.4.2 Bulleted or easy to find links [b] 1.4.3 Organized easy to find tabs [b]
2. Navigation [2, 4]	2.1 Accuracy [d]	2.1.1 The site provides or invites diverse perspectives (concerning mathematics such as pure or applied perspectives) [d] 2.1.2 Site does not contain obvious content errors or omissions [d] 2.1.3 Date of last revision in given on relevant pages (80% of the time) [e] 2.1.4 The information that is time sensitive appears to be updated regularly [d]
	2.2 Accessibility/Navigation [b, d]	2.2.1 Links work and are all functional, no coding errors [c, d] 2.2.2 Contact information is available and easy to find [d] 2.2.3 Convenient access to departmental information [b] 2.2.4 Links or Tabs for home page remain on all sub-pages [b]

Table 6 (continued)

3. Inclusion[1]	3.1 Diversity-Friendly Links [a]	3.1.1 Includes links to relevant internal organizations/resources [a] 3.1.2 Includes links to relevant external organizations/resources [a] 3.1.3 Includes links to organizations/resources for women and minorities [a]
	3.2 Relevance and Appropriateness [d]	3.2.1 Site provides appropriate information for graduate students [c, d] 3.2.2 Site provides appropriate information for faculty [c, d] 3.2.3 Site includes availability for contacting the webmaster
4. Aspirations[1]	4.1 Commitment to Diversity/Multiculturality [a, d]	4.1.1 Signal a commitment to diversity (gender and ethnic) from department rather than a piggyback from the university [a] 4.1.2 Commitment to diversity language should not be segregated on pages dedicated to the recruitment/retention of women and minorities, but should appear throughout the website [a] 4.1.3 Site is free of material that is oppressive to one or more groups of students [d] 4.1.4 Signal commitment to supporting graduate students at all levels
	4.2 Uses Science and Technology in the Real World [a]	4.2.1 Includes discussions of jobs and activities of graduates and/or those in the profession [a] 4.2.2 Includes information about how the profession and its members contribute to the welfare of society/ the physical environment and/or the wellbeing of people [a] 4.2.3 Outreach programs 4.2.4 Show women and minorities in active roles engaged in the field
	4.3 Characterizing Female and Male Students as Professionals [a]	4.3.1 Assures that photos and textual characterizations of women and men are harmonized throughout the website [a] 4.3.2 Includes names and forms of address, photos, biographical information, descriptions of research for faculty members (80% of the time) [a] 4.3.3 Includes names, address, photos of graduate students [a] 4.3.4 Professional experiences for graduate students are evident

Table 6 (continued)

5. Statements	5.1 Mission Statement	5.1.1 Explicitly stated [d] 5.1.2 Located on the homepage or linked from the homepage 5.1.3 Uses everyday language to convey goals [a]
	5.2 Diversity Statement	5.2.1 Explicitly stated [d] 5.2.2 Located on the homepage or linked from the homepage 5.1.3 Uses everyday language to convey goals [a]

Note: Below are listed citations form elements found within the table above

a. Burack & Franks (2006)
b. Montelone, Dyer, Burack, & Franks, (2006)
c. http://www.openc.k12.or.us/jitt/charact.html#UserFriendly
d. Gorski (1999)
e. Hunter (1999)

Each of the six UMDs was given numeric codes and a random number generator was used to choose the order of evaluation. The randomization of the order in which the websites would be evaluated was important because it did not give any website an advantage over another in terms of when it would be examined or which website was immediately evaluated before or after another. The evaluation of the six websites took place in the same day. The researcher then re-evaluated the websites a month later to make sure that the scores were appropriate.

Data Processing

The website evaluation results were a part of the data used to describe each of the six UMD participants. Other information on the website will provide secondary data collection for supporting student and faculty comments on both the Graduate Student On-line Questionnaire and in the interviews. The scores collected from the six UMDs in the study are displayed in Table 7.

Table 7
Evaluation Totals for Participating Mathematics Departments

	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea	Averages
Welcoming	9	9	9	9	9	9	9 (12)
Navigation Total	5	5	5	5	4	6	5 (6)
Inclusion Total	6	4	3	4	3	3	3.83 (6)
Aspirations Total	5	4	4	2.5	4	4	3.25 (9)
Statement Total	3	0	0	0	0	3	1 (6)
Rubric Total	28	22	21	20.5	20	25	22.75

Phase I

Phase I included all six UMDs and served several purposes in the study (see Table 8). First, it provided the entrance for UMDs to participate in a study that focuses on positive aspects of their departments and the rate of women doctoral graduates. Second, it allowed the researcher to collect public documents concerning the departments' public persona. Third, by looking at a number of UMDs, the researcher was able to view in broad strokes the mathematics community in which women participate. Six UMDs participated in Phase I and II. One of the six then participated in the case study outlined in Phase III.

Table 8
Phase I Outline

Phase I						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	DGP Phone Interview Document Collection					
Total Participants	6 Mathematics Departments 6 DGP Phone (or face-to-face) Interviews					

Participants

Phase I involved two levels of participants: the UMDs and the Directors of Graduate Programs (DGPs) or administrative equivalents of each of the UMDs. (For simplicity, the researcher will only use the term DGP in the writing of the report.) The DGP represented the UMD and provided the researcher with assistance during the data collection process for Phases I and II.

The six mathematics departments participating in Phase I was a convenience volunteer sample chosen from a purposeful sample of 25 UMDs fitting the criteria of the study goals (Creswell, 2007). Despite the small sample size, these six represent a wide range of types of universities, sizes of the university and mathematics department, geographical location and success rate in the recent past for graduating women mathematicians. Most of the information describing the participants was collected from the individual UMD websites. Therefore, the information reported here has been self reported by the UMD and may not accurately represent the number of people within the department; the researcher used approximations instead of actual counts. The final column in the table describes the characterizations of the graduate programs of the university as a whole according to the Carnegie Foundation. The Carnegie Foundation has 18 different classifications for categorizing graduate degrees offered at the respective schools. These classifications are "based on the level of graduate degrees awarded, the numbers of fields represented by the degrees awarded, and the mix or concentration of degrees by broad disciplinary domain" (The Carnegie Foundation for the Advancement of Teaching, 2009). The UMDs in this study represent only three of the 18 categories. Doc/STEM: Doctoral, STEM dominant institutions are those that award doctoral degrees in a range of fields, with the majority in STEM disciplines; they also may offer professional degrees in medicine or law. Comprehensive Doctoral with Medical and Veterinary category describes those institutions that award doctoral degrees in the humanities, social sciences, and STEM fields, as well as degrees in dentistry, medicine, and veterinary sciences. Finally, Comprehensive Doctoral with no Medical and Veterinary institutions award doctoral degrees in the humanities, social sciences, and STEM fields, but do not offer degrees in dentistry, medicine, and veterinary sciences. However they may provide degrees in other professional fields, such as business, education, engineering, law, public policy, social work, or the other health professions (The Carnegie Foundation for the Advancement of Teaching, 2009).

Instruments and Data Collection

In addition to the DGP interviews, the researcher collected documents concerning each of the UMDs. These documents included handbooks, recruiting posters, information booklets, and other publications. Such documents were considered supporting data sources, because they are not always accurate or free of bias (Yin, 2009). The most important use of these documents in both the collective case study and the in-depth case study is to "collaborate and augment evidence from other sources" (Yin, 2009, p 103).

During Phase I of the study, the researcher collected both university and mathematics department demographic information from the internet and college guide books. Demographic information collected included:

- Number of student enrolled at the undergraduate and graduate levels (size of university and mathematics department)
- Public or Private University
- Description of the Mathematics Department
- Programs Offered

This information was used to describe both the university and the UMD. Along with demographic information, the researcher collected public documents concerning recruitment of prospective students to the UMD. Public documents can be obtained without permission. These documents were accessed via the internet, collected from department brochures, and application information.

Secondly, the DGP at each institution was interviewed to provide internal recruiting and retention documents, speak about departmental issues and policies during a phone interview, and helped in preparation for an online survey to be given to graduate students in Phase II. Unfortunately, none of the DGPs provided internal documents, mainly because they reported such documents did not exist. Semi-structured interviews containing open ended questions were conducted with each of the DGPs (Gall, Gall, & Borg, 2003). The interview protocol consisted of nine main questions concerning the climate, diversity, recruitment, support, and retention of graduate students (Appendix K). Table 9 outlines the purpose and connection to the framework for each of the questions in the DGP interview protocol. The semi-structured nature of the interview and the open ended questions provided a greater breadth of responses than a structured interview (Fontana & Frey, 1994). The interviews were audio taped. The interviews (30-60 minutes) were conducted either face to face or over the phone.

Table 9
Purpose of DGP Interview Questions

<table>
<tr><th>Question</th><th>Purpose</th><th>Connection to Framework</th></tr>
<tr><td>1. Please describe the climate of your department</td><td>This question started a conversation about different types of relationships within the department</td><td rowspan="2">Community
The first question focused on the DGP's perspective of the department's climate how that climate affects relationships and interactions among faculty and graduate students as well as between the two groups.

The DGP will provide their perceptions of the department with relation to the graduate students and the interactions, relationships, opportunities for success.</td></tr>
<tr><td>2. Your department has been identified as one with a successful record of producing a high percentage of women mathematicians. What would you say are the strengths of your department that may be leading to that success?</td><td>This question provided the DGPs' perspective of the department and what he or she finds to be strengths. It also opened the door to finding out what recruitment practices the department employs.</td></tr>
</table>

Table 9 (continued)

3. Please describe the diversity in your department of faculty as well as graduate students.	The DGP described their perceptions of the diversity of their department.	Demographic information on the perceived diversity of the department
4. Can you tell me about the graduate student recruiting strategies?	This question asked the DGP to discuss recruitment strategies, both the overt ones, such as NSF funding and Math days for undergraduates, as well as more subtle decisions for attracting women to their department. Here the interview also explored the different ways departments recruit students, and why these are good strategies.	Domain What does the DGP think will attract more women to the program Practice What do they do to recruit students Community Which recruitment strategies focused on elements associated with the community
5. Can you tell me about your departments methods for screening graduate school applicants? Does gender ever factor into that process or affect decisions to accept an applicant?	This question helped to determine if gender plays a role in the graduate school acceptance rate. Do UMDs feel that men are better candidates, or do they accept men and women in equal to the proportion of applicants?	Community This will be telling about the departments practices and how they align with their recruiting strategies.
6. Does your department or college have any optional or mandatory diversity training for its faculty? Tell me about it.	This question explored what steps the institution or department has taken in ensuring that the faculty is knowledgeable about diversity on campus and in the department.	
7. What sort of academic or research opportunities or support do you offer your graduate students?	The purpose of this question was to find out what sort of training or opportunities students have access to during their graduate education.	Community and Domain What opportunities do UMDs provide for funding, learning the practice of mathematics and fostering relationships based on trust.

Table 9 (continued)

8. What sort of support is offered to students who are having trouble or thinking about leaving?	Here the researcher was interested in what types of mentoring students received when they were having trouble.	Community Support of students is linked to the social fabric of the department
9. Do you see your department as a community?	The purpose at the end was to have the DGP summarize if they felt their department was a community and in what ways they felt the department exemplified this.	Community The DGP is describing the climate of the department from a different perspective.

Data Processing

Each of the six DGP interviews was transcribed verbatim to be used during data analysis. Before coding took place the researcher read each of the interviews in their entirety. Each interview was "chunked" into like sections (Bogdan & Biklen, 2007; Creswell, 2003). The chunking, or breaking of the data into manageable pieces, allowed the researcher to search for patterns, organize the data into larger categories, and summarize each chunk (Bogdan & Biklen, 2007). The chunking of the data was initially based on the structured interview questions. Additional information obtained during the interviews was chunked together in an appropriate way. Codes were based on patterns found in the data as well as in the literature (Creswell, 1998; Yin, 1984). Interview codes were linked to the literature and the three elements of the Communities of Practice framework.

The researcher read the documents and recorded notes concerning their relevance to other data sources. The documents were examined a second time, specifically looking for wording or phrases that characterized specific aspects of the department in relation to the

Community of Practice framework. For example, the phrases stated how the UMD provided funding for students, or provided a department mission statement; these phrases helped the researcher determine the department's commitment to aspects of the community element. Another example related to both community and domain is how UMDs prepare their graduate students for experiences not necessarily related to mathematics content. Such experiences included preparing students for roles in academia through a series of seminars, preparing students for roles outside academia and other professional development seminars. The presence of these opportunities with a UMD implied that the UMD was not only interested in producing mathematicians, but in preparing graduate students for their future careers. A cross-case analysis across all six participating UMDs was used to identify themes within the documents that were common to all participants (Creswell, 1998).

Phase II

The data collected during this phase provided a broad look at students' perceptions of their UMDs (Table 10). A Graduate Student Online Questionnaire (GSOQ) was developed and used as the data collection instrument for Phase II (Appendix L). The questionnaire provided a brief look into the graduate students' perceptions of their respective mathematics departments.

Table 10
Phase II Outline

Phase II						
Collective Case Study Participants	Preston	Baldwin	Caldwell	Weston	Wagner	Chelsea
Data Collection	Graduate Student Online Questionnaire					
Total Participants	150 graduate students Student participants from all 6 universities					

In addition to the researcher's questions, the DGPs from each UMD had the option of adding up to three questions to the Graduate Student Online Questionnaire which was administered online during Phase II. These additional questions were unique to each university, therefore creating a need for six different questionnaires, one for each UMD. The DGP also aided in the solicitation of graduate students' participation during Phase II. As part of the incentive for UMDs to participate in the study, they choose to receive at the conclusion of the study the survey results from their respective departments. These results will be reported to their respective DGPs in the aggregate and participants will not be identifiable through their individual responses.

In the GSOQ, students were asked to describe factors for choosing their respective departments, and reasons for remaining in those programs. The GSOQ helped to determine the students' academic and career goals, and why they felt their programs should be recommended to prospective students. Each of these three topics aided the researcher in assessing the student beliefs and perceptions of the mathematics department and what elements of those perceptions were related to the Community of Practice as described by Wenger et al. (2000).

Participants

During Phase II, all the graduate students at the six participating UMDs were invited to complete an online questionnaire. The selection criterion for this group was to be a current graduate student in the participating UMD. The researcher asked each of the DGPs to send an email to all graduate students asking for their participation. The researcher wrote a letter of introduction that was to be sent with the graduate student email, asking for their participation in the study (see Appendix M), and included a link to each of the respective questionnaires. Graduate student participation was voluntary and no record was kept of who participated by either the researcher or the DGP at each university.

The final question on the questionnaire asked students if they would be willing to participate in an interview, and if so to provide contact information. This contact information was removed from the GSOQ responses. Contact information was, in no way linked to the questionnaire participants. Table 11 provides a description of the GSOQ participants from each university. By examining the table, one can see that 14% to 77% of the student body from each UMD responded to the GSOQ. Also, there was a wide range of students in terms of years in the program, ranging from first year students to students who had been members of their departments for more than 5 years. This gave the researcher a wide range of student perspectives.

Instruments and Data Collection

The questionnaire responses from the 6 UMDs comprised the data collected in Phase II. The GSOQ was designed using Survey Monkey (http://www.surveymonkey.com/) to be a cross-sectional questionnaire, in which data was collected at one point in time across the 6 mathematics departments (Creswell, 2003). Survey Monkey allowed the researcher to create, distribute and collect a large number of responses instantaneously for little cost versus a paper survey (Schonlau, Fricker, & Elliot, 2002). In the past, coverage error was the most recognized short coming of internet surveys (Schonlau et al., 2002). However, this error was not a problem in this study, since all the prospective participants were graduate students in doctoral granting institutions and had access to email and the internet while on campus.

Survey Monkey allowed the researcher to create unique questionnaires for prospective participants, collect the responses, do basic data analysis, and download the results to a spreadsheet. By basic data analysis, Survey Monkey reports the number and percent of respondents for each question, the number and percent of respondents that skipped each question, it can also create 5 different types of charts (pie, bar, line, column, and area) for representing the data. In addition, the site provides response percent for each multiple choice answer. Downloading the responses allows the researcher to see all of the answers to the open ended questions in relation to the other questions and by participant.

Each questionnaire consisted of 16 standard questions, and up to 3 DGP designated questions. Questions common to all six universities are found in Appendix L. The DGP questions were added to each participating UMD's respective questionnaire. In order to ensure that the additional questions were not harmful or discriminatory, the researcher and dissertation committee chairs screened and approved all additional questions. The questions added by the DGPs were not used in the data analysis for this study.

Table 11
Demographics of Questionnaire Participants

	Number of Participants from each University	Men	Women	Participants Number of Years in Program (Percent of Total Number of Participants)						Participant Program Enrollment (Percent of Total Number of Participants)	
				Less than 1 year	1-2 years	2-3 years	3-4 years	4-5 years	More than 5 years	Percent Master's Students	Percent Doctoral Students
Preston	42 (21%)	33.3%	62% [a]	11 (26.2%)	11 (26.2%)	4 (9.5%)	6 (14.2%)	5 (12%)	5 (12%)	2 (4.8%)	40 (95.2%)
Baldwin	14 (14%)	57%	43%	3 (21.4%)	5 (35.7%)	1 (7.1%)	1 (7.1%)	2 (14.2%)	2 (14.2%)	5 (36.7%)	9 (64.3%)
Caldwell	8 (40%)	37.5%	62.5%	2 (25%)	2 (25%)	0 (0%)	0 (0%)	3 (37.5%)	1 (12.5%)	1 (12.5%)	7 (87.5%)
Weston	31 (78%)	71%	29%	6 (19.4%)	7 (22.6%)	7 (22.6%)	5 (16.1%)	2 (6.5%)	4 (12.9%)	0 (0%)	31 (100%)
Wagner	15 (25%)	66.7%	33.3%	5 (33.3%)	3 (20%)	0 (0%)	2 (13.3%)	1 (6.7%)	4 (26.7%)	2 (13.3%)	13 (86.7%)
Chelsea	40 (20%)	67.5%	32.5%	11 (27.5%)	10 (25%)	3 (7.5%)	4 (10%)	5 (12.5%)	7 (17.5%)	3 (7.5%)	37 (92.5%)
	150 Total			38 (25.3%)	38 (25.3%)	15 (10%)	18 (12%)	18 (12%)	23 (15.3%)	13 (8.7%)	137 (91.3%)

a: two participants did not indicate a gender

The purpose of the GSOQ was to explore the students' perceptions of their UMDs and factors that influenced their decisions to attend and remain in their current programs. The GSOQ consisted of both multiple choice and open ended questions. Multiple choice questions were used to ease the students' responses and to gather demographic information. In some multiple choice questions not all possible answers could be listed, in these cases a dialog box allowed the graduate students to fill in an appropriate answer. The open ended questions were designed to allow the graduate students to write about their decision making processes involved in attending their current UMDs and their perspective of the mathematics community at each their UMDs. The graduate students were able to provide a brief look at factors that influenced decisions to apply to specific departments and to remain in those departments.

Only seven open ended questions were used in the data analysis; therefore Table 12 describes the purpose of only the open ended items.

Data Processing

Questions from the GSOQ were analyzed using both quantitative and qualitative methods. In order to describe the participants, three multiple choice questions were analyzed. These questions were:

D1 What is your gender?
D2 What degree level are you currently seeking?
D3 How many years have you been in the mathematics graduate program at your university?

The results of these three questions are found in Table 9 under *participants*. The seven questions listed in Table 12, were analyzed using qualitative methods.

The respondents typed their answers to the seven open ended questions; therefore the researcher had a record of their responses. Before any coding of the responses took place, the researcher read the responses in their entirety. This provided the researcher with a glimpse of the data and a 'feeling' for the larger picture concerning which experiences and factors the participants' chose to write about. The responses were "chunked" together according to each question (Bogdan & Biklen, 2007).

The responses to each open ended question were processed using serial tagging, analyzing each university's participants one at a time, and parallel tagging, reading and comparing responses from all 6 universities to the same question (Baptiste, 2001). The initial serial tagging and parallel tagging occurred using a subset of GSOQ responses so that a set of codes could be developed. Data was labeled, tagged, and coded based on emerging themes in the data (Baptiste, 2001). Tagging and coding occurred on two levels. First, the researcher looked at responses for each university separately. Second, the researcher looked for common themes and differences across the graduate students' responses from all universities.

Table 12
Purpose of the Analyzed Questions in the GSOQ

Question	Purpose	Connection to Framework
O1 Why did you choose to apply and accept admission to this university?	These two questions were designed to illicit responses about what factors students consider when applying and accepting admission to specific departments as well as remaining in departments after receiving master's degrees.	These questions were supposed to reveal elements of domain that the students considered, however they also revealed that the students consider elements of practice and community when applying to graduate school.
O2 Please provide any additional information that you feel would help me understand why you chose to become a member of your current department.		
O3 If you are working on a doctorate degree, did you complete you master's degree at your current university? Why did you choose to stay here or to leave a different university?		
O4 Would you recommend this program or department to prospective women applicants interested in studying graduate mathematics? Why? Or Why not?	These questions are designed to help gain a brief glance at the students' perceptions of their experiences within their respective departments.	These particular questions connected most closely with the community aspect. However, students addressed all three aspects of the Community of Practice.
O5 How would you describe the climate of your department?		
O6 If you could change one thing about your department what would it be and why?		
O7 Please describe some memorable experiences you have had within your department.		

Prior to coding, each university was assigned a color (red, orange, yellow, green, blue, or purple) and maintained the pseudonym (Preston University, Baldwin University, Caldwell University, Weston University, Wagner University, Chelsea University). The responses from each university for each of the seven open ended questions were printed on color paper corresponding with the color they were assigned. The responses were identified by gender and then separated and grouped by question.

Phase III

The purpose of the third phase (Table 13) of the study was to gain an in-depth perspective of one UMD through the use of a case study (Yin, 2009). Only by using an in-depth approach can one understand the department dynamics on a deeper level. The researcher got a glimpse of the individual UMDs in the first two phases as well as an understanding of the group as a whole, but these previous phases do not fully illustrate all the nuances of the department.

Table 13
Phase III Outline

Phase III	
In-depth Case Study Participants	Preston
Data Collection	Faculty Interviews Graduate Student Interviews New Student Survey
Total Participants	12 Faculty Interviews 17 Student Interviews 5 New Student Survey Responses

The researcher gained an in-depth perspective of Preston University through three sources of data: 1) doctoral student interviews, 2) faculty interviews, and 3) a “new graduate student” survey. The Community of Practice is about the entire community, therefore the perceptions and experiences of all members, both men and women, of the department are instrumental in providing this view.

Participants

Phase III of the study focused on one UMD. This UMD was selected from the subset of UMDs that stated they would be interested in participating in further researcher and based on the document analysis and questionnaire results. This department was selected because it had interesting GSOQ responses and DGP interview responses, as well as the largest number of participants in the GSOQ. The graduate students selected for interviews were doctoral students, pursuing a degree in pure or applied mathematics.

There were two methods for soliciting volunteers for the graduate student interviews. First, the student participants that stated they would be willing to participate in an interview on the GSOQ were contacted through email. The purpose of this email was twofold, the researcher wanted to verify their willingness to participate in an interview, and provided the prospective interviewees with more information concerning the study. Interview participants, who did not volunteer on the GSOQ, were also contacted through email obtained through the UMD. The UMD publishes their graduate students' names, offices, phone numbers, and emails on their department website. This list was used to contact via email prospective interviewees. Students who responded to the email request were interviewed at a time convenient for them. The researcher interviewed a total of 17 doctoral students. The interviews lasted between 35 and 90 minutes. Only 16 interviews were used, since during the interview it was determined that one student was an Operations Research doctoral student, housed in the math department. Table 14 outlines each of the student interview participants, their year in the program, if they had previously earned a master's degree, and their undergraduate institutions.

Table 14
Graduate Student Interview Participants

Participant	Year	Master Elsewhere	Undergraduate Institution	
SF1	1	No	Private	Small
SF2	Graduate	Yes	Public	Large
SF3	2	Yes	Public	Large
SF4	1	No	Private	Small
SF5	6	No	Private	Medium
SF6	5	No	Private	Small
SF7	6	No	Private	Small
SF8	2	No	Public	Large
SF9	1	No	Public	Large
SF10	4	No	Public	Large
SF13	1	No	Private	Small
SM1	2	No	Public	Large
SM2	4	Yes	Public	Large
SM3	1	No	Private	Small
SM4	5	No	Public	Large

Note:SF1 –indicates female student participant 1, SM2 – indicates male student participant 2,Undergraduate University descriptions are based on the Carnegie Foundation's Classifications.
http://www.carnegiefoundation.org/classifications/sub.asp?key=748&subkey=14270&start=782

The researcher recruited faculty members through personal emails located on the department faculty webpage. Every tenure track or tenured professor was emailed information about the interview as well as an overview of the study. Those that expressed an interest in the study were interviewed at their convenience. The researcher limited participation to tenure track professors, because these faculty members would most likely have the most opportunity to work with graduate students. Twelve faculty interviews were completed, seven men and five women. However only eleven interviews were used since the audio quality in one interview was too poor. Therefore, this participant was removed from the sample. Table 15 provides an overview of the faculty participants. New students who participated in the New Student Questionnaire in the fall of 2009 were the final group of participants in this study. The DGP of the program helped the researcher recruit these students. The researcher wrote a letter of introduction and email to the students, and the DGP forwarded it to all new students entering the program that fall. There were a total of 19 new students enrolled and 5 replied to the survey. This percentage (approximately 26%) is consistent with the response rate for the GSOQ administered the previous spring to current students. Table 16 provides a brief description of each participant.

Table 15:
Faculty Interview Participants

Participant	**Year's at University**	**Rank**
FF1	1-5	Assistant
FF2	1-5	Associate
FF3	16-20	Full
FF4	11-15	Full
FF5	6-10	Associate
FM1	26-30	Full
FM3	40-45	Full
FM4	31-35	Full
FM5	40-45	Full
FM6	16-20	Associate
FM7	1-5	Assistant

Note:
FF1 denotes female faculty member, participant 1, FM1 denotes male faculty member participant 1.

Table 16
New Student Questionnaire Participants

Participant [a]	**Undergraduate Institution** [b]		**How did you hear about the Mathematics Graduate Program here?**
NSF1	Private	Medium	2009 Mathematics Meeting in Washington DC
NSF2	Private	Small	Current Math Student
NSF3	Private	Medium	Email from Undergrad department
NSM1	Attended College Internationally prior to pursuing a PhD		Advisor from Undergraduate
NSM2	Private	Very Small	Family Member

Note: a: NSF1 – New Student Female Participant 1, NSM1 – New Student Male Participant 1
b. Undergraduate University descriptions are based on the Carnegie Foundation's Classifications.
http://www.carnegiefoundation.org/classifications/sub.asp?key=748&subkey=14270&start=782

Instruments and Data Collection

The researcher spent several weeks at the UMD interviewing graduate students and faculty members. The researcher conducted semi-structured interviews using a series of structured questions as well as using open-ended questions (Gall et al., 2003). Doctoral graduate students participated in a 35-90 minute interview concerning their experiences within the UMD, decision making process for attending graduate school, and that questions concerning the climate and perceptions of that UMD in particular. All graduate student interviews followed the same protocol (Appendix N). See Table 17 for an explanation of each of the questions and their connection to the framework.

Table 17
Purpose of Graduate Student Interview Questions

Question	Purpose	Connection to Framework
1. Tell me about being a student in this program/department. 2. Please describe the climate of your department	These two questions revealed what factors and experiences the students choose to highlight when discussing their department.	These questions looked at the students perceptions of the graduate community within their departments Responses to the first question also addressed aspects of the graduate mathematics department that are connected to practice.
3. Your department has a record of graduating a large percentage of women doctorates; did this impact your decision to attend this particular school?	The goal of this question was find out if the participants are aware of gender/diversity issues in the mathematics community, and if these issues were a part of their decision making process.	Domain and Community If gender did not play a role in their selection of mathematics department, they may have explored other reasons for attending their university which may fall into either of these categories.
4. Looking back, can you describe how you decided to pursue a Ph.D. in mathematics, describe any experiences that may have influenced you along the way?	These questions helped to explore why the participant choose mathematics and a graduate degree.	Elements of Practice and Domain may be determined through responses to this question.

Table 17(continued)

5. Are you currently employed by the mathematics department? Tell me about your responsibilities.	This question is designed to inquire about funding opportunities that the participant takes advantage of. Further, this question inquired about other types of support (other than money). Do the students feel they have the support of a mentor or advisor in pursuing their degrees?	Community – support for students through adequate funding opportunities, mentoring, advising, and faculty/role models. Also, it brought out aspects of the domain of mathematics through students preparation for careers outside of academia
6. How does your department prepare students for different types of careers?	This question is designed to explore what types of training or preparation graduate students think they receive in helping them prepare for future careers	
7. Please describe some experiences you have had with faculty members.	This is designed to explore the participant's experiences with faculty advisors, role models, and mentors. The active pursuit of a specific advisor would lead to questions concerning why they chose that person.	All of these questions had close ties to the community element of the Communities of Practice. The answers to these questions helped to describe what aspects of the department in relation to the community. This question was concerned with the participant's identity development in the mathematics department (community)
8. Do you think that your gender has affected your pursuit of an advanced degree, in what ways?	This question asks the students of their gender awareness in the study of mathematics.	
9. What advice would you give to a young woman or man just starting their graduate degree in mathematics?	These questions helped the researcher to discover what the experiences the students felt were influential to their graduate school education, and which of those they wish to pass on through future interactions or advice to new students.	
10. What experiences did you have as a graduate student that might influence your interactions with future graduate students?		

Table 17(continued)

11. If you had the opportunity, what would you change about your graduate experience?	This question helped illicit experiences or thoughts that the students felt could be improved. It was not meant to gather negative information.	The students talked about aspects of the department that they felt could be improved. Theses aspects could have connections to all three elements of the CoP

During the site visit, the faculty members also participated in a 30-60 minute interview. These interviews also followed a semi-structured protocol with open ended questions (Appendix O). However, the protocol was different from the interview protocol used with the graduate students. The faculty interview questions addressed their experiences within the UMD, their decisions to become faculty members in that particular UMD, and recruiting and retention efforts of the UMD. Table 18 explores the purpose and connection to framework for the interview questions (please see Appendix O for follow up questions).

Table 18
Purpose of Faculty Interview Questions

Question	**Purpose**	**Connection to Framework**
1. Can you please describe how you decided to become a mathematician?	Explored the interviewees past and look at the factors and decisions they made when choosing to become a mathematician Follow up questions were used to encourage the faculty to think about social or cultural variables	Domain – this question explored why the faculty member became interested in mathematics and working at a Doctoral granting department Community the questions explored the participants past perceptions of the mathematics community through their graduate school education, and their professional development
2. How long have you held your current position?	These questions lead into why faculty members choose to accept jobs and stay in their current positions. This was to draw out facts about the department, that the faculty feel are positive for both faculty and graduate students. Also, there were things that kept the faculty members in their current position as well as might attract new faculty or graduate students.	Demographic information Domain and Community – this question examines examined their current perceptions of the UMD and why they choose to work in that particular department
3. Tell me about being a faculty member in this department.	This question helped the researcher get a feel for the faculty members perceptions of the department, and what their role in the department was.	Practice, Community, & Domain All three aspects of the Communities of Practice were described by faculty members.

Table 18 (continued)

4. What experiences did you have as a graduate student that has influenced your interactions with current graduate students?	This question helped determine the practices that faculty members were employing with their own students. If they had good experiences, were they providing similar ones for their students? If they had poor experiences were they trying to provide better ones for their students?	Domain and Community – this lead to an exploration of past and present perceptions, experiences, and influences that the faculty member feels are important to the education of their current students. It reveals some of the department's dynamics in terms of what opportunities are provided for graduate students. As well as explored the faculty's perceptions of those opportunities
5. What sort of academic or research opportunities or support do you offer your graduate students?	These three questions asked the faculty to think about the mathematics community in terms of what they offered to the students as opportunities outside of coursework, the general environment of the department and what they felt where mentoring techniques that aided in the students being successful in the program and department.	This question addresses issues of climate through the faculty members' perceptions of their department's environment, reflection on their mentoring styles, and the types of opportunities that are available for students. Question 5 also addresses issues within domain and practice.
6. Describe the culture or environmental dynamics of your department.		
7. Highlight some of the hallmarks of your mentoring style.		
8. What do you perceive are the most important things that graduate students walk away from their program knowing?	This question was asked to determine what the faculty members felt the most important for the students to learn during their graduate program.	This question specifically asks what the faculty feel are the most important part of the graduate program. These responses can range in topics and make connections to the domain, practice, or community elements.

Table 18 (continued)

9. Are you aware your department has been identified as one with a successful record of producing women mathematicians? . What do you think are some of the factors that might contribute to this record?	Faculty are asked to reflect on the possible reasons for why so many women may be attracted to their program, and factors that may contribute to their success within the Mathematics Department.	This question is also connected to the community aspects.
10. Do you see your department as a community?	This question addressed how faculty members felt about their department climates and the relationships between faculty, graduate students, and between the two groups.	Community This question examined the participant's perception of the interactions and relationships between faculty members, students, and between faculty and students.

The last piece of data collection took place in Fall 2009 with a "new graduate student" questionnaire (NSQ). New graduate students to the UMD were asked to complete an on-line questionnaire asking about their experiences and perceptions of the graduate mathematics department upon arrival to campus and during the first few weeks of courses. This data collection was specifically timed to coincide with the new school year, so that the students would be reflective on how the department (both faculty and students) welcomed and prepared them for the upcoming school year, and their chosen programs. The NSQ consisted of twelve multiple choice and open ended questions (see Appendix P for entire questionnaire). The multiple choice questions were used to describe the participants in the study. The open ended questions were designed to discover how the new students perceived their entrance into their chosen mathematical community. Table 19 outlines the purpose of the questions on the NSQ and their connection to the framework.

Table 19
Purpose of NSQ Questions

Question	Purpose	Connection to Framework
1. What is your gender?	These questions were used to gather information for the purpose of describing the participants	These questions were purely for demographic reasons and are not connected to the framework.
2. Are you beginning a Master's program or PhD program?		
3. Where did you earn your bachelor's degree?		
4. Where did you earn a Master's degree (if applicable)		
5. How did you hear about the Mathematics Graduate Program at your University?	The purpose of this questions was to find out how the students learned about Preston University	Prospective students can learn about universities through a variety of ways that are related to the domain or community of that UMD.
6. Describe your impression of the collegiality among faculty and graduate students within the department.	The purpose of this question was to assess the new students' perceptions of the atmosphere of the department through their observations how well the people in the department work together.	These questions addressed the community of the UMD.
7. What activities or events did you attend that were sponsored by the department? How were these activities or events helpful in making your transition to graduate school?	These two questions look at how the community enfolds new members into it, and what activities they employ to encourage students to become involved in the community.	

Table 19 (continued)

8. What has the department done to make you feel welcome?		
9. What are some things that you like/enjoy about the department?	This question asks students to recall specific events, activities, people, or courses that they have enjoyed within the first few weeks of the semester	This question can yield results that are related to the community, domain or practice of the mathematics department.
10. Have you had any disappointing moments within the department thus far? Explain.	This question asked about disappointing experiences or expectations that the students may have had that were not met upon arrival on campus.	The responses to these two questions may be connected to all three aspects of the Community of Practice Framework.
11. What are your expectations for the upcoming year, in relation to graduate student and faculty relationships, coursework, advising, and TA or RA responsibilities?	The purpose of this question was to gage what the new students were currently focused on in terms of expectations for their entry into the graduate program or the mathematics department.	
12. Describe any experiences *outside* the department that were particularly impressionable (positive or negative) during these first few weeks?	Here the students are describing any events or activities that they have participated in with other members of the graduate mathematics community that may not have been sponsored by the department or the university.	This question is connected to the community element and how students and/or faculty interact outside of the department.

Data Processing

All interviews were audio-taped and transcribed for data analysis. The researcher read each of the interviews in their entirety. Each interview was “chunked” into like sections (Bogdan & Biklen, 2007; Creswell, 2003). Codes were based on patterns found in the data as well as in the literature (Creswell, 1998; Yin 1984), as well as those codes created from earlier data analysis of the GSOQ. The themes in the graduate student interviews are anticipated to be related to the literature on departmental characteristics and factors that contribute to attrition of graduate students, while the themes in the faculty interviews may be related only to the departmental characteristics.

Student and faculty interviews were initially considered separately during data analysis for a variety of reasons. The two types of interviews follow different protocols and are seeking different types of information, as well as different perspectives pertaining to the mathematics community. Each of the two groups provided a unique perspective of the community, since their participation is different, and it is unlikely that members of the faculty were students within that community as well. The NSQ added to the interviews by contributing to the graduate student perspective, by examining how the department and its current members welcome new students and indoctrinate them into department. The NSQ responses were read in their entirety and coded using themes already created.

The next section will discuss in more detail the data analysis for each of the research questions, and how that analysis aided in answering those questions. The research questions to be answered in the following chapters are:

R.1 *What are the characteristics of graduate mathematics departments that have a relatively high percentage of women doctorates in mathematics?*

R.2 *How do the characterizations of the graduate mathematics departments influence the graduate students and faculty members' experiences of the community within one particular large mathematics department?*

R.3 *How are the three aspects of the Communities of Practice framework related to the characteristics of the graduate mathematics departments?*

Data Analysis for Research Questions 1 and 3

The researcher analyzed data from Phases 0, I, and II to answer Research Questions 1 and 3. As described above, the analysis used the Mathematics Department Websites and links to other departmental and program information from Phase 0. Such information included graduate handbooks, and program descriptions not found on web pages. The DGP interviews from Phase I and the GSOQ from Phase II were also used in the data analysis.

The GSOQ provided the majority of data with 150 graduate students answering all or some of the questions. Many participants skipped questions on the GSOQ, for unknown reasons. Thus, the unit of analysis in the GSOQ was the questions and the corresponding responses

From the GSOQ, seven questions were analyzed. The researcher chose these questions because they were the only open ended questions (some had multiple choice parts) given to all six universities in the on-line survey. None of the demographic or multiple choice questions were used in this stage of analysis. The seven questions were:

O1 Why did you choose to apply and accept admission to this university?
O2 Please provide any additional information that you feel would help me understand why you chose to become a member of your current department.
O3 Why did you choose to stay here or to leave a different university after completing a master's degree?
O4 Would you recommend this program or department to prospective women applicants interested in studying graduate mathematics? Why or Why not?
O5 How would you describe the climate of your department?
O6 If you could change one thing about your department what would it be and why?
O7 Please describe some memorable experiences you have had within your department.

The first two questions were analyzed together, because the second question was a continuation of first. Table 20 shows the number of responses analyzed for each of the 7 questions.

Table 20
Number of Responses for Each Question Analyzed in GSOQ

Question	**Responses**							**Percent of Total GSOQ Participants**
	Total Number of Unique Responses	**Preston**	**Baldwin**	**Caldwell**	**Weston**	**Wagner**	**Chelsea**	
Questions O1 and O2	85 unique responses	22	6	6	21	5	25	56.7%
Question O3	87	30	5	3	17	8	24	58%
Question O4	86	26	8	5	16	6	25	57.3%
Question O5	79	24	7	5	16	7	20	52.7%
Question O6	67	19	5	4	15	5	19	44.7%
Question O7	57	16	3	2	15	3	18	38%
Total Number of Responses	462 total responses	133	34	25	96	34	129	
Number of Students participated in the GSOQ		N=42	N=14	N=8	N=31	N=15	N=40	N=150

Coding of GSOQ Open Ended Questions

The coding of the GSOQ's open ended questions took place in four stages. Figure 3 provides a flow chart for the four stages of the coding. The responses to the open ended questions were descriptive and ranged from single word answers, to responses which were several sentences long. Therefore the coding of all seven open ended questions followed a similar protocol. There were four stages of coding. In the following sections, each state is explained in greater detail.

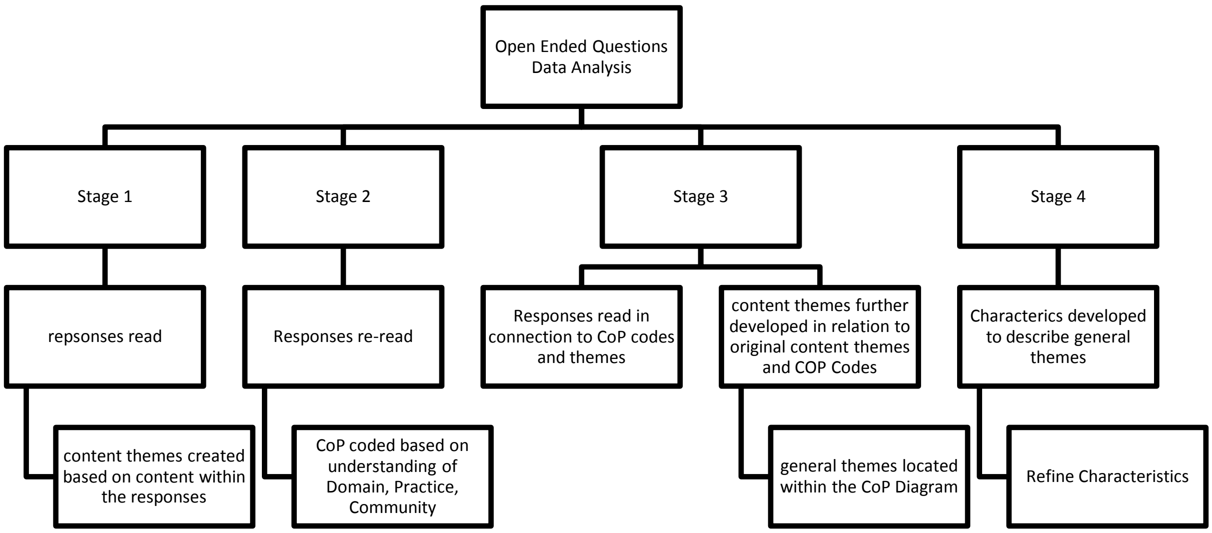

Figure 3: Coding of Data

Stage 1

The researcher began analyzing the data by open coding each of the seven survey questions (Creswell, 2007). This meant that the data was coded for its major themes. Therefore, as the responses for each question were read, a list of themes that appeared in the context of the responses was created. The content themes were short, usually one or two word descriptions of what the participant was describing. For example: the following complete quote broken into bullets was in response to "Why did you choose to apply and accept admission to this university?" from a Preston University student exemplifies how the response was coded in several different content themes.

- *There was a recruitment weekend which allowed me to visit and see campus and meet people which was a plus.* [recruitment]

- *Also, I'm on a TA-ship which is a large part of why I came. Funding was important to me.* [financial support]
- *The thing that made my final decision for me was the collegiality among the math grad students here. At other schools the grad students are in competition and here we feel like we're all one big family.* [environment/atmosphere]
- *Older grad students helped me immensely before I came and during my first year (and continue to). They helped me pick classes, recommended housing, gave me tours, took me out to eat, introduced me to people, etc. It just felt right when I visited.* [people in the department]

Each of the four highlighted sections of the response above produced a different content theme. In bullet one, the student discusses visiting during a recruitment weekend, therefore the theme became recruitment. In the second bullet, the student talked about the importance of funding in choosing a program. The third bullet represents what he or she considered the catalyst in making the decision to attend Preston University; this was related to what he or she saw as the environment or atmosphere. Finally, the last bullet represents a section of the response that was coded in "people in the department". The student talked about how the more advanced graduate students helped his/her adjustment to graduate life and to life in a new city. Therefore a single theme was not used to describe the entire content of a response, but rather to categorize pieces of the responses.

As content themes were created from the responses, they were used in subsequent responses to different questions as part of a coding system. However, new content themes were added as necessary. For example Question O3 was coded first. The themes that resulted were 1) Atmosphere and Environment, 2) Financial Support, 3) Location, 4) Relocate/Family Responsibilities, 5) People in the Department, 6) Always Planned to Stay/Combined Program 7) More Research Opportunities, 8) No Doctoral Program at

Previous University, 9) Leaving and Starting Over too Much Trouble, and 10) Don't Currently Have a Masters. Each of these themes was then considered in the coding of the next open ended question, O1 & O2. Some themes appeared in responses from multiple questions, while other themes were specifically related to the content derived from a single question.

After the initial list of content themes was created, the researcher then collapsed content themes into larger categories because several of the original themes were related. An example of collapsing occurred with the "people in department" theme, instead of having a theme for the discussion of students, faculty or both together, the researcher placed all such responses into the same category. Following the initial development of the themes, a second round of open source coding was completed to refine the codes and tease out definitions. Table 21 lists all the themes gleaned from the open ended questions, a short description of the themes, and the questions in which they appeared.

Table 21
Themes from Open Coding

Theme (Question[s] in which they appears)	**Description**	**Number of times a Theme appeared**
Always planned to stay (3)	Students that applied to doctoral programs did not feel that they wanted to change nor even considered it.	26
Atmosphere/Environment (1, 3, 4, 5, 6, 7)	any mention of the climate, environment or general atmosphere of the department	98
Change of Heart (1)	A few students talked about changing degree programs or leaving doctoral programs for master's degrees	2
Diversity in Gender (1, 4)	Many talked about the large number of women in their departments	34

Table 21 (continued)

Diversity in Research (1, 3, 4, 6)	This included the responses that discuss the research opportunities for graduate students, as well as research opportunities that were available.	26
Don't have a masters (3)	Some students chose not to earn masters, and others had not completed them yet	13
Enjoyment of time, Like math (1, 4)	generic responses of Math is fun, I like being here, I have enjoyed my time here	9
Financial Support (1, 3, 4, 6, 7)	Monetary reward, Assistantships, or funding opportunities for graduate students	26
Lack of Commitment (4, 6)	Students unwilling to state if they would recommend or not to women graduate students, or stating that they would recommend the program to both men and women.	25
Lack of Options (1)	Many students accepted enrollment at their programs simply because it was the only one in which they were admitted.	6
Leaving and starting over too much trouble (3)	Students stated that they stayed in programs because leaving would cause setbacks and time delays in graduation	3
Location (Geography) (1, 3)	Students stated that they liked the climate (weather) and location of the universities they chose	18
No Doctoral Program (3)	Some students left previous institutions because there were no doctoral programs available	4
No Memorable Experiences (7)	Students stated that they did not have any or could not think of any memorable experiences	8
People in Department (1, 3, 4, 5, 6, 7)	Response that includes mention of people, whether in general or specific groups or individuals. Does not include statements about the department is friendly. May include the graduate students are friendly though	148
Program Description (4, 5, 6, 7)	General descriptions of the programs themselves (may be combined with Atmosphere/Environment). Also included responses about students interpretations of the department without any real proof of the statement being true	58
Program Recommendation (1)	The program or school was recommended to the student by advisors, students or family members	15

Table 21 (continued)

Qualifying Exams (1, 6, 7)	Students talked about their exams, choices, stress, studying for them…	8
Recruitment (1, 7)	Students talked about recruitment efforts, including visiting universities for recruitment weekends	18
Relocation/Family Resp. (1)	Some students talk about other obligations that factored into their choices of school	8
Reputation of University, Department, or Faculty (1)	Students considered the reputation of the university, department, or particular faculty members	19
Size of University (1)	In some cases the size if the university rather than the department was a factor in making decisions.	6
Social Events (5, 6, 7)	Students talk specifically of social events both within and outside the department	29

After the completion of the beginning content themes for the open ended survey questions, the researcher reexamined O5, where some of the students used one word responses to describe the climate of their departments since she did not want to ignore these answers. They were grouped them into four main categories; Welcoming, Accessible, Causal, and Dedicated. Table 22 shows which types of responses fell into which of the four groups. Participants from all 6 universities produced one-word responses that fit into one of these 4 groupings.

Table 22
Categories for Climate Responses

Welcoming	**Accessible**	**Causal**	**Dedicated**
Friendly	Open	Relaxed	Busy
Comradely	Helpful	Laid-back	Dedicated
Collegial	Supportive		Ambitious
Warm			Focused
Close-knit			Intense
Familial			Challenging
Protective			

Stage 2

The purpose of *Stage 2* was to determine if there was a connection between the open-coding and the theoretical framework of the study. Therefore, this stage involved a coding the responses to the open ended questions based on the Communities of Practice framework (Wenger et al., 2002). The coding was anchored in the researcher's understanding of Wenger et al.'s (2002) definitions and descriptions of the three Communities of Practice elements: domain, practice and community. This understanding was further refined by dialogues during the coding process with advisors.

The coding protocol followed a similar pattern to that of Stage 1. The previous content themes were ignored during this Stage, and each response was coded using the Communities of Practice Framework. Each question's responses were examined and coded separately as either D, for domain, P for practice, or C for community. At this time, response components were coded strictly domain, practice, or community, with no attention paid to the possibility that a component might be more than one of the three aspects.

However, as coding progressed, it was noted that some of the responses contained components that fit into more than one of these three areas. To make sure that the Communities of Practice codes were appropriate, they were categorized and then checked against the descriptions of domain, practice, and community, and, if necessary changes were made. Responses that were questionable were discussed with faculty advisors and agreement was reached before proceeding.

The researcher notes that not all responses to the questions were assigned a code according to the Communities of Practice in this third round. For example, responses that concerned applying to a specific UMD's program which related to geographic location were labeled with an N and not used in constructing the image of the graduate mathematics Community of Practice. Location does not appear to be related to the Communities of Practice framework in connection with graduate mathematics departments, because it cannot be changed or altered by the department.

Stage 3

This stage involved further developing and refining the content themes from Stage 1 and the Community of Practice codes from Stage 2. The researcher conducted a re-sorting of the responses in relation to the Communities of Practice codes from Stage 2 and the content themes from Stage 1. The purpose was to look for common elements between the two different types of codes; open codes and Communities of Practice Codes. She examined how responses were coded and looked for commonalities within each of the original themes from the open coding and how those subjects were related to the Communities of Practice framework. As a result, additional categories of general themes were developed by either breaking down larger content themes, or collapsing and subsuming other content themes into a single theme. Below is a list of the general themes. Each of these general themes is discussed in detail in the following chapter, therefore only a list will be provided here.

List of General Themes from Open Coding

- Freedom of Choice in Qualifying Exams
- Foreign Language Requirement
- Past or Practice Exams Posted on Website
- Seminars and Colloquia
- Teaching Professional Development
- Attending conferences and Presenting at conferences
- Resources for growth, i.e. Library
- It slows you down to switch institutions
- Earn master's degree in route to PhD
- No doctoral Program at previous university as reason for leaving.
- Social Activities outside department
- Advisor role
- Program Recommended
- Funding
- Recruitment
- Reputation of University and/or Math Department
- Faculty area of specialty, want to work with faculty in that area
- Diversity of Research
- Size of the department
- Geographic location
- Family Obligations/Responsibilities
- Office space of the graduate students
- Collaboration between graduate students
- Open and supportive Faculty
- Respectful and understanding Faculty
- Familial Atmosphere
- Success of students is important to everybody
- Welcoming
- Faculty and student demographics
- Social Events Within the Department
- Enjoyment of Math
- Like the Program
- Department Teas
- Common space

Stage 4

Stage four consisted of organizing and further defining and combining the codes. To help characterize the UMDs with large percentages of women, categories (new broader based themes) were created for grouping similar codes together. All of the themes from the open coding were initially grouped according to themes among the codes. These broader based themes were discussed and refined during research meetings. The new themes are: Intrinsic Motivations, Attractants, Department Characteristics, Professional Growth, Exam Practices, Master's to PhD Route, Student to Student Interactions, Multi Student to Faculty

Interactions, Single Student to Single Faculty Interactions, and Faculty Characteristics. These groups were then used to define characteristics of the UMDs. These themes were further refined to general characteristics of the UMDs and the graduate student body. These characteristics and their respective descriptors are discussed in detail in Chapter 4.

Coding and Analysis of DGP Interviews

The data from the DGP interviews was used as a secondary source in answering research questions 1 and 2. In order to make the data more accessible, open coding of the interviews was used to describe large amounts of content. The interviews were coded after the GSOQ and therefore the researcher used the open codes from the GSOQ as well as some new codes created for describing content that appeared in the interview but not in the GSOQ. First, the interviews transcripts were read in their entirety and then “chunked” into 12 sections (see Table 23) based on the interview protocol (Bogdan & Biklen, 2007; Creswell, 2003). Each section contained the DGP responses about a particular aspect discussed during the interview.

Table 23
Twelve Topics Discussed During DGP Interviews

Applicant screening	Atmosphere/Environment
Community	Diversity Training
Diversity of Student Body and Faculty	Financial Support for Graduate Students
Mentoring	Teacher Training Programs
Recruitment	Research Experience for Graduate Students
Successful record of Producing Women Doctorates	Other Types of support for Graduate Students

Several of these topics are related to the general themes which emerged in the GSOQ coding process (see List on page 47). For example, *Atmosphere/Environment* is representative of the same types of responses in both the interviews and the GSOQ because the DGPs and GSOQ participants were asked to describe the climate of the department. However, there are also topics from the DGP interviews that are not found in the GSOQ responses. This is a result of using a different protocol in order to seek different points of view from the DGP interviews, and the GSOQ. Therefore topics of discussion such as *applicant screening* or *diversity training* did not appear in the data from the GSOQ.

Data Analysis for Research Question 2

The Preston University case study provided insight into one UMD that is successful in producing women mathematicians. The case study interviews offered in depth details about how the participants experienced or perceived Preston's mathematics department.

The faculty interviews were examined first, because they would reveal a faculty perspective of Preston University's Mathematics Department through the characteristics and descriptors developed for answering the first research question. They would also enrich characteristics and descriptors which were developed from the perspectives of the students and the DGPs. The faculty interviews allowed the researcher to develop descriptors that are unique to the faculty members of the department.

The student interviews were read and coded second. They also provided data that enriched previous characteristics and their descriptors as well as providing a basis for creating new descriptors.

Using the five characteristics and their descriptors developed during the data analysis for research questions 1 and 3 the interviews collected during the case study were examined. Each set of interviews, graduate student and faculty was read. Next they were coded using the descriptors as codes. The researcher used the list of descriptors as a basis for the codes; however during the reading of the interview bullet points were added to the descriptors and a list of the interviews was kept highlighting how many students commented on a specific descriptor (see Figure 4 for an example). The bullet points provided a deeper understanding to how the students and faculty perceived each of the descriptors. The bullets also helped to enhance the descriptors in the discussion in Chapter 5.

Advisor role • Supportive • Network • Preparation for career • Good at asking questions instead of giving answers • Guide research	Faculty interviews: FM1, FF2, FF3, FF4, FM3, FF5, FM5, FM6 Graduate student interviews: F6, F10, F2, F7, F5, M1, M2, M3,M4, F12, F8, F3

Figure 4: Example of Interview Coding

During the first and second readings the researcher noted additional themes that were present in at least two interviews but were not present in the descriptors created from the GSOQ. Many of the new themes were created from the faculty interviews. This is not surprising because the GSOQ did not address faculty perceptions, experiences, or concerns. A new list of themes was created that corresponded with the descriptors and characteristics already developed. For example, under the broad heading of *environment* faculty members highlighted four additional themes: (1) faculty are supportive of students and of each other, (2) the department is family friendly, (3) faculty enjoy working with students and helping them through transition stages, and (4) faculty feel that they have a degree of freedom in pursuing their research interests, collaboration with others, and in choosing where to publish their research. The themes were further refined and incorporated into the characteristics and descriptors from the data analysis of Research questions 1 and 3. The new characteristic and its descriptors, along with new descriptors for the original five characteristics are discussed in detail in Chapter 5.

Validity and Reliability

Stake states that interview protocols help to ensure accuracy. The need for triangulation is to confirm the validity of process (1995 as cited in Tellis, 1997b). There are four types of triangulation: data source, investigator, theory and methodological (Denzin, 1984 as cited in Tellis, 1997b). Data source triangulation was achieved in this study because of the variety of participants in each of the three phases. Each data source provided a different view of the same community. The expectation was that the data from each UMD participant would be similar in some aspects across universities, as well as the experiences of participants within the different UMDs.

Also adding to the validity of the study is the fact that many different types of data were collected (Tellis, 1997b). Documents provided stable information that existed prior to the study (Altheide, 1996; Bogdan & Biklen, 2007; Tellis, 1997b). Interview data was collected from three different areas within the UMD; DGP, graduate students, and faculty members. These provided a focus on the community from three different perspectives and help to triangulate the data. Data from all six universities was collected over several weeks. The extended time of the data collection helped to reduce observer bias.

Pattern matching and explanation building during the data analysis helped to ensure internal validity (Yin, 1994). Pattern matching occurred during the data analysis at each phase and at the conclusion of the study. It involved relating several pieces of information from the same case to theory (Yin, 1994). The theory was derived from the literature review on women in STEM and communities of practice using the words from the stewards of the discipline.

The researcher created a case study database and maintained the chain of evidence in order to help ensure the reliability of the data; all of these methods help to ensure construct validity (Yin, 1994). Peer examination was employed to aid in ensuring the validity and reliability of the researcher's interpretations of the data and the coding techniques employed (Merriam, 2002). Discussion of the coding and samples involved the dissertation committee chairs. This helped to ensure reliability in the codes and the coding of the data. Finally, the six universities that received aggregate data from the survey were able to provide feedback on the data if they wished.

The next three chapters explore the results in terms of the three research questions.

CHAPTER 4: CHARACTERIZATIONS OF GRADUATE MATHEMATICS DEPARTMENTS

Introduction

The purpose of this chapter is to answer the following research question.

R1. What are the characteristics of graduate mathematics departments that have a relatively high percentage of women doctorates in mathematics?

The primary data used to help answer this question were the Directors of Graduate Programs (DGP) interviews from Phase 1, and the Graduate Student Online Questionnaire (GSOQ) open ended responses (listed below) from Phase II. The University Mathematics Departments (UMD) websites and their rubric analysis from Phase 0 were used as secondary sources to confirm or disconfirm and to provide more details. The analysis of these data as discussed in Chapter 3 allowed me to identify five primary characteristics across the collective cases of UMDs.

- *Graduate students are attracted to these UMDs for a variety of personal and universal reasons.* [Attractants]
- *These UMDs provide a welcoming and diverse environment for graduate student success.*[Environment]
- *These UMDs provide different structures for supporting their graduate students throughout their academic careers.* [Academic Support]
- *These UMDs facilitate opportunities for interaction among its members.* [Interactions]
- *Graduate students create opportunities for interaction and value the relationships formed from such interactions.* [Relationships]

Each of the characteristics of the UMDs is discussed with respect to its descriptors (which are a result of the open ended coding).

These characteristics and their respective descriptors are listed in Table 24. Descriptors are the general themes from the final round of coding that are elements of each of the characteristics. Descriptors help to provide more details about the characteristics. Only descriptors found in data sources from more than one university appear in the table as way of describing a particular characteristic of the UMD. General themes from the open coding that only appeared in the data from one university are not discussed in the results nor presented as a descriptor for the characteristics, because those particular codes may have been a result of a characteristic which is unique to that particular university. For example students at Preston University talked about attending conferences with their advisors as a means of professional growth; however, no other students from other UMDs mentioned this activity. Faculty at the other five universities may take their students to conferences, but there was no evidence of this practice in the data.

Table 24
Characteristic and Respective Descriptors generated from GSOQ and DGP Interview Coding

Characteristic		Descriptor	Universities
Attractants	**Personal**	Program recommended	Caldwell, Baldwin, Preston, Weston, Chelsea
		Geographic location	Baldwin, Wagner, Preston, Weston
		Family obligations/responsibilities	Caldwell, Baldwin, Weston, Chelsea
		Limited options in graduate programs	Baldwin, Preston, Weston, Chelsea
		Satisfaction with choice of program	Preston, Weston, Wagner, Chelsea
	Universal	Diversity of research	Preston, Weston, Chelsea
		Size of department	Caldwell, Preston, Weston, Chelsea
		Reputation of university and/or department	Caldwell, Preston, Weston, Chelsea
		Faculty areas of research	Baldwin, Preston, Weston, Chelsea
	Both	Financial Aid	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
		Recruitment	Preston, Weston, Chelsea

Table 24 (continued)

Environment	Faculty value success of students	Caldwell, Wagner, Preston
	Friendly and welcoming	Preston, Weston, Wagner, Chelsea, Baldwin, Caldwell
	Perceptions of gender issues	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
	Gender diversity among faculty and students	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
	Open and supportive faculty	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
Academic Support	Colloquia and seminars [a]	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
	Teaching and professional development	Preston, Weston, Chelsea
	Departmental resources for growth, i.e. Library	Baldwin, Preston, Weston, Chelsea
	Exam practices	Preston, Baldwin, Weston, Wagner, Chelsea
	Alignment of Master's and PhD	Baldwin, Wagner, Chelsea, Weston, Preston, Caldwell
	Financial aid [a]	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
	Diversity of research [a]	Preston, Weston, Chelsea
	Graduate student office space [a]	Caldwell, Preston, Chelsea
	Collaboration between graduate students [a]	Caldwell, Wagner, Preston, Weston, Chelsea, Baldwin
	Advisor role [a]	Wagner, Preston, Weston, Chelsea, Baldwin
	Faculty accessibility [a]	Weston, Chelsea

Table 24 (continued)

Interactions	Graduate student office space [a]	Caldwell, Preston, Chelsea
	Collaboration between graduate students [a]	Caldwell, Wagner, Preston, Weston, Chelsea, Baldwin
	Colloquia and seminars [a]	Caldwell, Baldwin, Wagner, Preston, Weston, Chelsea
	Social events within the department	Preston, Baldwin, Weston, Wagner, Chelsea, Caldwell
	Advisor role [a]	Wagner, Preston, Weston, Chelsea, Baldwin
	Faculty accessibility [a]	Weston, Chelsea
	Regularly scheduled department teas	Preston, Weston
	Common spaces	Preston, Weston
Relationships	Graduate student office space [a]	Caldwell, Preston, Chelsea
	Collaboration between graduate students [a]	Caldwell, Wagner, Preston, Weston, Chelsea, Baldwin
	Social activities outside department	Baldwin, Preston, Weston, Chelsea, Wagner, Caldwell
	Informal mentoring of younger students from more senior students	Caldwell, Weston, Chelsea

Note: a descriptors may appear in more than one characteristic

The sections that follow provide a detailed account of each characteristic and the descriptors of each. Examples from the data will be used to illustrate the findings.

Attractants

Graduate students are attracted to these UMDs for a variety of personal and universal reasons.

Students experienced a range of experiences, perceptions, and desires that led them to enroll in specific programs or departments and to pursue degrees within those departments.

There are two different types of attractants that emerged in this study, personal and universal. Personal attractants were those that have a distinct link to the graduate applicant or member of the graduate student body; in other words, the student has an investment in that specific attractant. Universal attractants were ones that have no special or personal connection to the student. These included descriptors such as the reputation of the university, reputation of the mathematics department, reputation of a particular faculty member, diversity of research and the size of the department. There were two descriptors that fell into both the universal and personal attractant categories; financial aid and recruitment. The following sections described how the personal and universal attractants influence student choice in selecting an UMD.

Personal Attractants

Personal attractants included factors students considered when choosing which schools to apply to and which to accept admission, as well as why students remained at their respective universities after completion of a Master's degree. The students were invested in or connected to these factors in some special way. These include program recommendations from a variety of people that the students were in contact with, knew personally, or whose opinions they respected. Geographic location and family responsibility were also personal factors that some students considered. Personal desire to live in a specific region of the United States due to climate or nearness to family are unique to an individual, but also considered in the decision making process for choosing an UMD.

Program recommended. There are two different categories of recommendations. First, applicants value recommendations made by those associated with the department such as current faculty or graduate students, alumni, former faculty, or external faculty and graduate students working with those within the UMD. The second category refers to those that have no direct association with the department; this could include an undergraduate advisor, parent, friend, or someone else that has heard about the graduate program. Fifteen students from five of the universities mentioned in written responses that recommendations played a factor in their applying and accepting admission to a specific graduate program. They mentioned recommendations from undergraduate advisors and faculty, REU supervisors, friends, and current students in the departments in which the participants were expressing an interest. Only students from Wagner U did not mention any type of personal recommendation to the UMD in their written responses. However students from all six universities selected *recommendation from current or former students* as a factor in their decision making for the multiple choice question (see Figure 5). Thus, it is apparent that receiving a recommendation for an UMD from someone with whom an applicant has a personal relationship and who considers the UMD good enough to recommend is an important and valuable way to attract graduate students to a program.

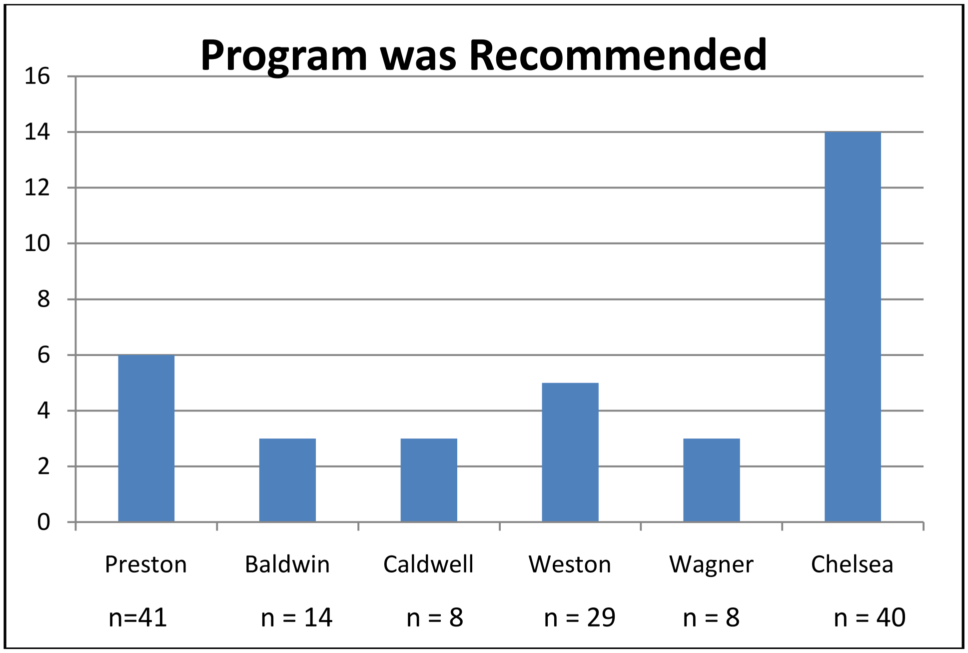

Figure 5: Number of students from each university that considered recommendations to a UMD from current and/or past students

Geographic location of university. The location of the university was found in responses to two different questions on the GSOQ. The first question which had responses coded geographic location was O3: Why did you choose to stay here or to leave a different university after completing a master's degree? There were 7 responses to this question that involved geographic location as a reason for staying at a current UMD after receiving a master's degree. Six of the seven responses simply stated the student enjoyed living in the area surrounding their respective schools. The seventh response was related also to living near the school, but had connections with a spouse's career also being the area. All seven of these students also selected "location" as a reason for choosing to apply and accept admission to their particular UMD in O1. And, in fact, seventy-four of the 146 (50.7%) GSOQ participants selected the location of the university as a factor in choosing to apply and accept admission to a particular UMD (see Figure 6). Of the 74 students to check location of the university, 8 of them explained this further in a free response. These 8 responses, plus 4 more which were coded in Stage 1 as Geographic Location are discussed in the next few paragraphs.

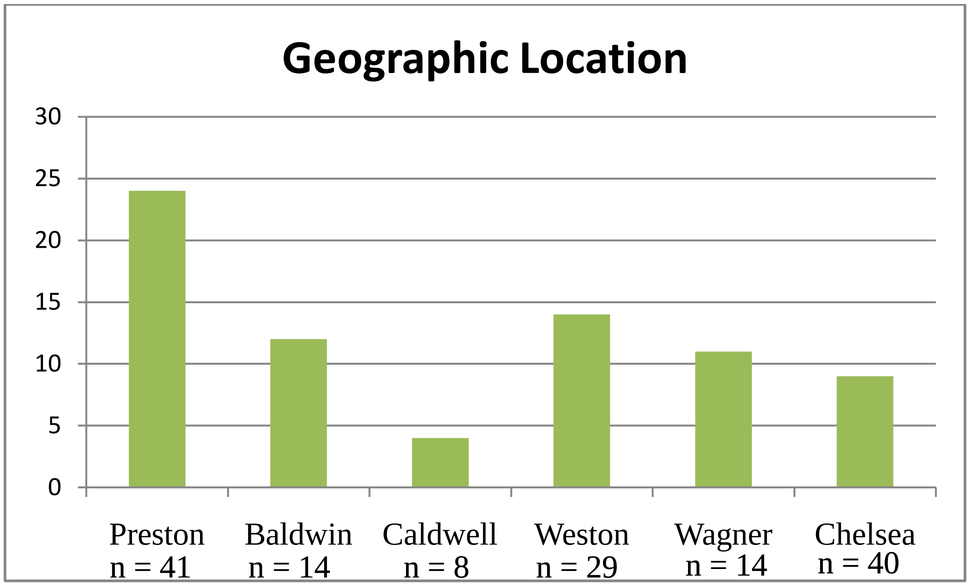

Figure 6: Participants who chose location of university as a factor in choosing an UMD

Location seemed important for reasons of convenience and enjoyment of the geographic area and being apart from family. For example, two students at Baldwin University were living in the area and wanted to study graduate mathematics in a convenient setting. So they applied to Baldwin University because they were already living in that region. One of these students, wanted to study graduate mathematics as a hobby, and stated they would not have pursued it if Baldwin had not been located in the vicinity. Another student applied because it was easy to apply, and they could get started on a graduate degree in mathematics and then move to another UMD. However, this student did not move programs because they were offered “very good funding, and couldn’t pass it up”. One student enrolled in Wagner University simply stated that he “loved [city]” and accepted admission. In other words, these three students were tied to their respective cities and wanted to study graduate mathematics. Similar to this feeling of connectedness, a graduate student enrolled at Preston University felt that because she had lived in the area for approximately 12 years, she had heard a great deal about the local universities and knew their strengths and weaknesses, making Preston seem like a good choice for her.

Other students gave reasons for choosing a university based on being *away from* family. For two of the students, one attending Weston University and the other attending Chelsea University, they wanted to leave home, and attend graduate school away from family and friends. The student from Chelsea wanted to “enjoy a different math environment than from my undergraduate school, away from acquainted friends and [I] wanted to meet new faces, away from parents and siblings so that I can get some work done”.

Family obligations or responsibilities. Responsibilities to families served to enhance the attractiveness of some UMDs based on their location. Twelve of the 146 students selected family responsibility as a factor in choosing or accepting admission to a specific university. Of the 12 students who chose this response, seven were men and 5 were women. This possibly indicates that within this sample, family obligations or responsibilities were just as important to men as they were to women.

Four students took their partners’ careers and educational goals into account when choosing an UMD. One example of this was in a Baldwin University student’s response; he stated that he and his partner were looking for graduate programs in very different fields and needed a location that would provide both of them with opportunities to pursue graduate degrees in their respective fields. A Weston University student accepted admission to that particular school because he felt it was a better location (than the other graduate school options) for his wife to find a job. Often the "two –body" problem in academics refers to faculty positions or careers (Philipsen, 2008). Here we see that graduate students also consider their partner/spouses' goals and careers in conjunction with their own, and those places that offer opportunities for both partners are more attractive.

Limited options in graduate programs. Another factor that is connected to both the graduate program and a person's own motivations is a lack of options. If a student wants to go to graduate school in mathematics, and they apply to several programs, but are only accepted to one of those programs, that limits their options. They are left few options, they can find a job and apply again in a year, find a job and not reapply, or attend graduate school in the program in which they were accepted. Several of the participants in this study, 6 from three universities stated that their current programs where the only options they had if they wished to attend graduate school. The reasons for this lack of options however vary. Four students said that their program was the only one that accepted them. One student wrote that it was the only school that accepted both him and his wife. This student had external factors affecting his decision as well including the importance of his wife being accepted to graduate school. The last student applied late to his undergraduate institution and they accepted him as a master's student with the option of changing programs later. For these six students, the lack of options in choice of graduate school did not deter them from enrolling in the programs which accepted them.

Satisfaction with choice of program. Experiences within departments can affect a student's graduation success and cause them to leave a department, and possibly mathematics (Herzig, 2002a). However, twenty six students from Preston, Weston, Wagner, and Chelsea Universities stated that after enrolling in their respective graduate programs they liked the program and felt no desire to leave it. For example: "I was very happy with the program; I liked the people in the department and also enjoyed living in this area; and I also had the security of being fully funded" (Weston University Student).However, there was one student at Caldwell University who wrote about leaving a doctoral program. She explained that after passing her qualifying exams, she no longer wanted the PhD, and that if she did not want the degree anymore, it was not worth the time and effort to get it. Instead, she decided to enroll in the Master's program to complete a degree. Without more evidence we cannot connect her changing to the masters program to some factors or issues connected with the department members or with the program.

Universal Attractants

This type of attractant is more formal and more applicable to a wide variety of students and faculty without drawing on their personal characteristics, needs, or beliefs. These were considered to be more "fact" about the department rather than factors that influenced individuals. Universal attractants included the reputations of the university and the mathematics department, size of the department, diversity of research areas within the department, and faculty areas of specialty.

Diversity of research. Diversity of Research was a theme that ran through four of the open ended questions. There were only a total of 20 responses spread over O1, O3, O4, and

O6. In answering the questions about choosing to apply and accept admission to their current UMD, some students were undecided or unsure of what area of mathematics they wanted to study in graduate school and may have felt more comfortable applying to departments in which there was a breadth of fields being researched by the faculty. Students from the two largest universities, Preston University and Chelsea University mentioned that they preferred the wide variety of research areas for them to choose from. By attending graduate school in larger departments, students could have an opportunity to participate in classes and small research projects from different areas of mathematics before deciding on a research agenda for their dissertation.

Four students stated that they changed UMDs after completing their Master's degree because they wanted a wider variety in terms of research opportunities and areas of mathematics available for exploration. One student pursued their degree at Chelsea University because he was attracted to the large number of faculty in a wide variety of mathematics fields. This attraction may indicate that students who are unsure of which field in mathematics they wish to pursue, want to have different options, and therefore choose larger more diverse (in terms of research areas) departments.

In addition, four of the UMDs websites (Preston, Baldwin, Weston, and Chelsea) listed courses and research areas in both pure and applied mathematics (University Websites, 2009). A student from Weston University mentioned that his department had close links to pure and applied mathematics as well, and was tied closely with the Physics department. Preston University advertises that they offer an interdisciplinary mathematics program and further inspection of their website shows that they offer PhDs in interdisciplinary mathematics and work closely with related fields.

Size of the department. In connection with *diversity of research,* one must look at how students perceived the size of their respective departments. Participants from four of the universities (Caldwell, Preston, Weston, and Chelsea Universities) commented on the size of the department as being a factor in choosing to attend the UMD. However, the size of these universities varied greatly from Caldwell University (approx. 20 graduate students) to Preston and Chelsea Universities (each approx. 200 graduate students). The students from Caldwell University liked the small nature of their department allowing for “lots of personal attention” (GSOQ respondent, Caldwell University). Students attending the smaller UMDs felt that the nature of the smaller departments provided a more friendly and personal relationship between the faculty and the students. Some felt that it was easier to get to know fellow graduate students and faculty members than it would be in a larger department. DGPs from the smaller departments also felt that it was more difficult for students to “fall through the cracks” than in larger departments. However, members from the larger departments viewed the size of their departments as a benefit. They felt that the departments’ sizes provided them with the opportunity to explore area of interests and find a research topic that suited them. Thus, for some graduate students, they seemed to have chosen an UMD that fit their needs and personal comforts.

Reputation of university or mathematics department: The reputation of either the university or the math department was an important factor for students from four of the participating institutions to consider. Students from all six universities indicated that either the reputation of the university or the reputation of the mathematics department played a role in their choice in selecting that university for application or for enrollment (see Figure 7). Forty four students from all six universities stated that both the reputation of the university and mathematics department were of influence.

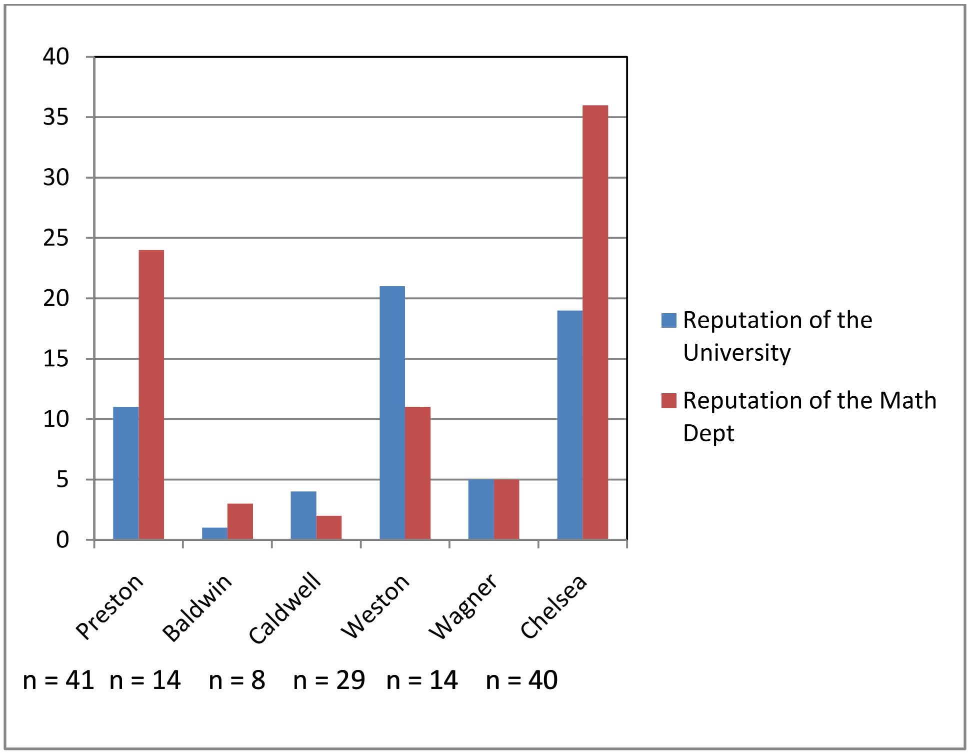

Figure 7: Number of students from each UMD who chose reputation of the university and/or reputation of the department as one of the reasons for applying and accepting admission to a particular UMD

Faculty areas of specialty: Faculty reputation was also a universal attractant. In some cases, the faculty's areas of specialty was what attracted students to a particular department. This attractant ranged from knowing a single faculty member from a previous experience such as working with that person on a REU (Research Experience for Undergraduates) or from word of mouth. For example, a student enrolled at Weston U accepted admission in part because his undergraduate advisor told him that the department had good geometers and strong relationships with the physics department. One student attended Baldwin because he believed that he wanted to work in Number Theory and there was a particular faculty member who was strong in that area at this specific university.

Both Personal and Universal Attractants

Two attractants were labeled as both personal and universal. The reason for their dual ranking was due to how the students and DGPs referred to them. If an attractant was described as being beneficial to all students or existing for all students then it was considered a universal attractant. If the attractant was discussed in relation to a specific quality or need of the student, then it was considered a personal attractant. The two descriptors that fit into this categorization are *Financial aid*, and *Recruitment.*

Financial aid. Funding was considered a both a personal and universal attractant in this study. The difference was in the way in which the students discussed it.

Funding as a personal attractant seemed influential for the students participating in the GSOQ. This was the most common choice for accepting admission to their given programs when answering O1, as a large number of students (n=104) indicated that they considered funding as a factor (Figure 8). What is also evident in Figure 8 is that a high proportion of respondents from each UMD considered funding in their decision making.

Funding appeared in the open coding for five of the open ended questions; O1, O3, O4, O6, O7. In the open ended section of O1, the students reiterated how important the funding was to their decision. Of the twelve students who replied, eleven of them stated that they accepted admission at an UMD, because they offered funding (or the best funding opportunities). The other student stated that "funding was important to me" (Preston University, Graduate Student), but not the sole reason for attending Preston.

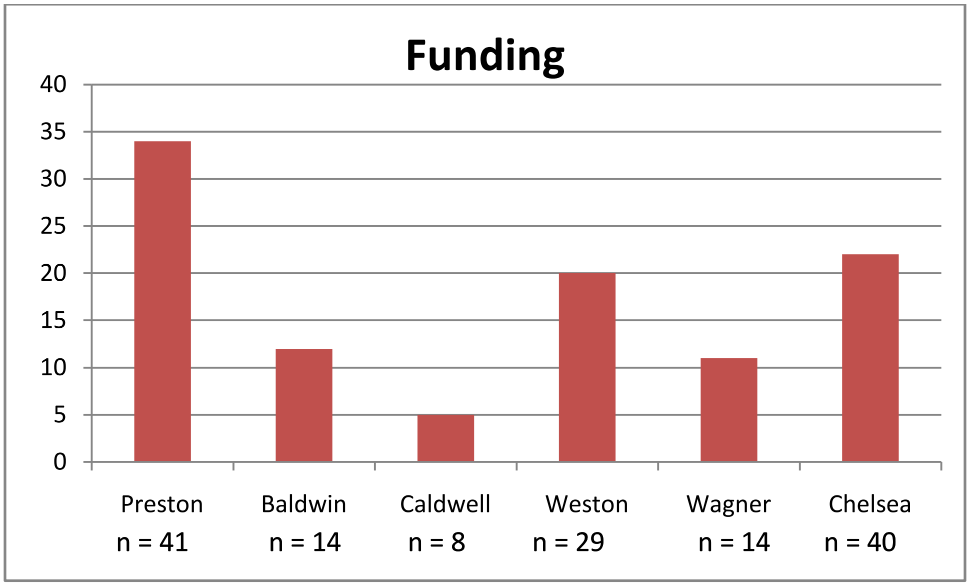

Figure 8: Number of students from each UMD that selected Funding as a factor for accepting admission

Funding also plays a role in students' decision to continue their studies at their current universities. In five responses (out of 87) for O3 students mentioned that their funding was not in jeopardy. These students may have felt comfortable in continuing their studies at their respective UMDs because they did not have to worry about their funding. Other individuals were concerned about length of available funding or worried about the budget situations that may affect graduate student funding. For example, one student from Weston University wanted the length of funding extended from five years to five and a half years. A student from Chelsea University stated that faculty "scared them" every semester about funding situations. However she gave no further explanation for her feelings. Past research has found that funding during graduate school can impact a student's success in their program, with students who are not funded having significantly higher attrition rates than those that receive funding (Herzig, 2004a; Lovitts, 2001).

Two students mentioned funding as part of their memorable experiences within the department. A Preston University female student stated that last year was one of the "best and the hardest. I received a scholarship award and teaching assistant award". A Chelsea University male student told of how his advisor went the extra mile to procure funding for him while he was visiting family in Taiwan during Christmas break. Another student (also from Preston U) stated that she recommended the UMD to her undergraduate peers because of the funding opportunities.

For funding to be a universal attractant, it needs to be discussed without relationship to individuals. All 6 of the DGPs referred to funding in this manner. Further, the DGP interviews revealed funding was important for their graduate program. This point was exemplified in the fact that DGPs from Preston, Caldwell, Weston, and Wagner Universities stated that all of their graduate students are funded, and most of the graduate students from Baldwin University and Chelsea University are funded as well. An examination of the UMDs websites illustrated that opportunities for funding is provided to all students, signaling a commitment to students at all levels.

Recruitment. Recruitment fell into both the personal and the universal attractants categories. Recruitment is the act of finding and attracting new students to a graduate program. Most of the recruitment that occurred before the application process was wide-scale in nature to advertise the program and attract applicants. For example, Wagner University's DGP stated that they published an ad in the Assistantship and Graduate

Fellowships in the Mathematical Sciences (American Mathematical Society, 2008). Upon further inspection, the researcher found that Caldwell, Chelsea, Preston, and Weston Universities also published advertisements in this brochure and that Wagner, Weston and Chelsea Universities also had full page advertisements for their respective departments. Another form of recruitment via advertisement was exemplified by Weston University's Poster of Graduate Studies in the Department. This poster is found on their department's website.

UMDs had a variety of other recruiting strategies for attracting prospective students. These strategies include holding recruitment weekends for prospective students, waiving application fees based on some criteria, displaying posters describing the graduate programs at other universities or at conferences, or having faculty members attend graduate school fairs across the country.

Baldwin University and Wagner University's DGPs felt that their universities had more subtle recruitment techniques that were outside the control of their universities. For example, their location in regions of the United States which are particularly known for their beauty and recreation opportunities also help to draw students (and faculty) to those locations. Also, the regions in which those universities are located also have a large number of national science labs and industry, making the universities a convenient and locale option for continuing the education of employees of the surrounding science labs and industries. While these regional advantages and science labs are not controlled by the UMD, it does not mean they do not help to attract students to the area.

DGPs from both Preston University and Weston University talked about the type of students they try to attract. At Preston University "we target non-Research 1 universities, such as small colleges, where there are still excellent students" [DGP interview]. Weston University also looks toward the small good colleges for their graduate students. Both of these schools also stated that they try to target domestic students and address gender equity in mathematics without sacrificing the quality of the students they admit. These strategies are supported by the fact that a large proportion of women who go on to earn doctorates in the STEM fields earn undergraduate degrees from liberal arts colleges rather than from universities (Thom, 2001).

Other types of recruitment discussed by the DGPs were much more subtle and informal. For example, professors attending conferences may discuss their programs with students attending those same conferences, and within formal recruiting weekends there may be more informal gatherings of current and prospective graduate students in which prospective students can learn about the program and members of the department.

The websites of each of the UMDs also revealed different techniques for attracting students. Caldwell University does not require an application fee for its graduate students. Preston University's mathematics department pays the application fees for those students applying with GPAs of 3.6 or higher. Weston University waived the application fee for students who score above a specific cutoff on the GRE. This technique was mentioned by several Weston students as an incentive to apply to the graduate program. No students from Preston or Caldwell mentioned waived application fees.

In terms of more active recruitment techniques, all six of the UMDs hold recruitment "weekends" or organized visits to the university for prospective students that have already been accepted to the program. Once accepted, prospective students are invited to attend a recruitment weekend, in which they tour the campus, meet faculty and current graduate students, and often attend classes or seminars. Ten students from Preston University and Weston University mentioned the importance of attending the recruitment weekend. They stated that they got to meet the other prospective students, current students, and faculty members of the department. In these cases, they felt they got a good "feel" for the departments and the visits helped them to decide. An example of this was illustrated by a female student from Weston University, "I knew Weston has a strong reputation as both a university and as a mathematics department. When I visited for recruitment weekend, the faculty seemed laid back and welcoming, and the students seemed to really enjoy being here."

In terms of the GSOQ, 12 (of 146) students from Preston, Weston, and Chelsea Universities stated that they were recruited to their respective departments when answering O1. The low number of students being recruited is not surprising since Chelsea University, Caldwell University and Baldwin University's DGPs stated they did not employ active recruiting strategies for finding or attracting students.

Environment

These UMDs provide a welcoming and diverse environment for graduate student success.

Each of these six departments is described as friendly and welcoming by the students and the DGPs. Further, the students discuss the gender diversity of the student body as being important to their experience. This section discusses different descriptors which emerged from the data that support the characteristic that the UMDs are supportive and welcoming of all their students.

Faculty value success of students

From the DGPs' perspective, the departmental faculty are invested in the success of their students. They want all their students to be successful and do not aim to "weed out" or decrease the graduate student population after they have been admitted to the program. Partly, this desire to have all their students succeed may stem from the fact that the six UMDs fund almost 100% of their graduate students. It can be a waste of resources and time for students to be admitted to a program, receive funding and then for them to leave the program without completing the degree (National Research Council, 1996).

The students also expressed a belief that their UMD was supportive of all its students and wanted them personally to be successful in the program. The responses showed that the students felt the professors were interested in their learning and genuinely wanted them to succeed. The professors did this by creating nurturing environments and having in place policies (whether university wide or departmental) that allowed students to "balance" personal and school lives. Students from both Preston and Baldwin University commented on their department's family friendly faculty.

Friendly and Welcoming

One of the reasons often stated for the attrition of women in the STEM fields is the "chilly climate" environment (Blickenstaff, 2005; Sandler, 1999; Strenta et al., 1994; Whitt et al, 1999). Chilly environments tend to be cold and unfeeling toward underrepresented groups, and possibly other students, unconscious behaviors by faculty can accidently (or intentionally) single out or ignore specific groups of students (Hall & Sandler, 1982). However, there is very little evidence to support that the students in these six UMDs felt that there was a “chilly climate”. On the contrary the students reported in 43 different responses that their departments were friendly and open environments that supported student learning and progress toward degree in their programs. There were three responses (from three different universities) that addressed specific instances of people with unfriendly attitudes. However, students describing these instances did not portray negative feelings toward the department or members of the department overall. For example a graduate student from Caldwell university explained “

> *The atmosphere is pretty nice. There are a few jerks that make you feel down about yourself, but if you ignore them it's not so bad. It's easy to let yourself get overwhelmed, but I have a feeling that's true about any graduate program. On the whole, I'd say it's a friendly place to be.”*

In addition, all six DGPs specifically used the word *friendly*, when asked about the climate of their departments.

In all seven open ended questions, students from Caldwell, Chelsea, Preston, Wagner, and Weston Universities discussed how welcoming they felt their departments were in 44 different responses. The responses included descriptions of faculty, graduate students, and staff as being nice and polite. They felt that there was a sense of community within their respective departments, and many of the students could not recall having had negative experiences during their graduate programs. Student may feel more comfortable working in welcoming environments that are friendly and vested in the success of all their students. For example a female student from Wagner University affirmed, “I felt comfortable when I visited the department. The faculty and graduate students were all very nice and welcoming and they seemed to be happy here.”

Baldwin University did not have any students describe their department as welcoming. The interview with Baldwin’s DGP revealed some possible reasons for this. In recent semesters, the Baldwin was losing mathematics professors and not being permitted to conduct faculty searches to replace the empty positions. This has placed extra strain on the professors remaining in the department. They have had to take on extra responsibilities and more advisees. The DGP still felt that the department was welcoming and supportive of students, but also admitted that the students could tune into the strain on the faculty and possibly perceive the department to be less welcoming than it had been in the past.

Perceptions of Gender Issues

For the students, feeling comfortable and welcomed also included having gender diverse populations in the department. Many students, both men and women, when asked if they would recommend the program to prospective women, mentioned that there were a lot of women in their department already so women might consider the environment more inviting.

Many students reported that they had not been the victims of or seen incidents of gender biases in their departments. However, it is possible that issues of gender bias and sexism are present, but they are not noticed. It is also possible that this knowledge would be passed on to prospective women students during the recruitment weekends as well as information concerning issues of sexism. For example a female student at Weston described the following in answering the O4 in recommending women applicants,

> *Some in our department would like to "warn" applicants of issues of sexism in our department. Yes, they exist. However, I believe the only way to change the mentality is to bring in more women, especially strong candidates, to change the status quo. I have not had any direct issues with professors and sexism, and as such, I will not discourage any female from applying. Perception drives reality. If we are perceived as a department without issues of sexism, we will become just that. It will take time, and it is a gradual change, but not recommending the department to potential candidates will only worsen the issue.*

This woman feels very strongly about what she saw as promoting perceptions to applicants, and offered suggestions for addressing the issues. Other students, men and women, believed that they did not feel that they were treated any differently by members of the department because of their gender and that the department welcomed all their students. Some students felt that their universities were making a conscious effort to diversify their departments. For example, a student from Wagner University explained,

> *I have never felt that this department treated me any different because of my gender. And there is a running dialogue in the department about their desire to attract, retain, and support female graduate students. And we have several senior professors who are women.*

Gender Diversity among Faculty and Students

Faculty and student demographics were limited in this study to questions focused on gender, mostly because that was part of the focus of the study. Demographics are used in this study to describe the number of women students or faculty in the department. Rarely did students or DGPs provide exact numbers; instead they gave estimates, or described their impressions of the number of women in their departments.

Throughout the open-ended responses on the GSOQ, references to faculty and/or student demographics were coded 39 times, with the majority of these responses addressing why students chose to accept admission to their current universities and why they would recommend the program to prospective women students. A female from Caldwell University stated that one of the reasons she "decided to apply [and] accept admission to this university was that there were several more women listed on both the graduate student and faculty pages on the department website". This also an example of a possible benefit to UMDs if they post pictures of graduate student and faculty members on their websites. Preston University and Caldwell University were the only two UMDs that posted pictures on their websites of both faculty members and graduate students.

Students from all six UMDs stated they would recommend their programs to prospective women graduate students because they had already had "a sizeable number of females amongst the graduate students in the department" (Chelsea University, Male Graduate Student). However, only students from Preston and Chelsea Universities, the two largest UMDs in the study, specifically mentioned the number of women faculty. For example, one Chelsea University student stated "There are several very active research-wise female faculty and a women in mathematics group that holds a weekly seminar [and] lunch as well as a semester get-together over desserts."

Open and Supportive Faculty

In 44 different responses to the open ended questions in the GSOQ, the students describe the faculty in a variety of ways that suggest a perception of faculty as open and supportive. These terms open, supportive, respectful, and understanding seemed to be used interchangeably and often in connection to each other. Therefore, these themes will be discussed as a group with examples provided by the data.

The students describe the faculty as being open. This can be interpreted to mean that the faculty was accessible and willing to help students outside of class on course work. This willingness to help outside of class is also discussed under the descriptor of *Faculty Accessibility*. Faculty members are also instrumental in helping the students make the transition from undergraduate programs to the graduate program, a transition that may be difficult (Golde, 1998). Students appreciated that faculty's efforts in helping them make that transition through accessibility, for example that "everyone has been very willing to help me transitioning from undergrad. I have enjoyed working with the majority of professors I have encountered" (Weston University, Graduate Student). A Chelsea University student felt that "most professors are available and always willing to help"

Students in this study also considered the staff in the UMD when describing the climate. The staff members are key members in the department as well. They help the students with administrative issues, such as locating keys for offices, making copies, and preparing handouts for courses they are teaching. A Baldwin University Female student's response exemplified this, "the staff tends to be very understanding and always available to help students."

Students from Chelsea and Weston Universities expressed that they felt their faculty was open and supportive on the whole, but that there were specific members of those faculties which were not as supportive. For example, "there are some professors, mostly older, who come off as unfriendly and unsupportive" (Weston University, Male Graduate Student).

Academic Support

These UMDs provide different structures for supporting their graduate students throughout their academic careers.

The descriptors described in this section are institutional and faculty driven. This means that they are a part of the culture of the UMD and are already implemented as expectations by the faculty.

Colloquia and Seminars

Colloquia and Seminars are typically directed by the department and are sponsored by different faculty members. While colloquia and seminars are often open to the public, there are regular participants from the faculty and graduate student body that will attend the meetings. Colloquia are "academic meetings at which specialists deliver addresses on a topic or on related topics and then answer questions relating to them" (2009, In *Merriam-Webster Online Dictionary*, retrieved September 15, 2009, from http://www.merriam-webster.com/dictionary/colloquium). All six of the mathematics departments list both seminars and colloquia as part of their websites, and provide monthly and yearly schedules for these. The colloquia in these mathematics departments include both internal presentations (given by faculty from the department) and external presentations (given by invited speakers) and are open to faculty and graduate students to attend. .

A seminar is defined as "a group of students studying under a professor[s] with each doing original research and all exchanging results through reports and discussions" (2009, In

Merriam-Webster Online Dictionary, retrieved September 15, 2009, from http://www.merriam-webster.com/dictionary/seminar). Each of the six mathematics departments list a wide variety of different seminars in which students and faculty can participate. The researcher discovered, either through the department websites or talking to the DGPs, all six of the universities have at least one seminar that is run by the graduate students for the graduate students. These seminars typically allowed faculty only by invitation. Both faculty and graduate students can present research during a seminar. Baldwin also listed dissertation and thesis defenses on their calendar for seminars.

Teaching and Professional Development

This particular theme included departmentally organized teaching and professional development as well as those organized by the graduate schools within each university. Most graduate students get their funding from Teaching Assistantships (TAs) (DGP interviews, 2009). Different departments offer their own teacher training methods. Three of the UMDs offer department-wide teaching seminars and support for first year students. The TAs typically have a faculty member that provides administrative support: a person that they can talk with about teaching methods, classroom management, or specific issues relating to students. This faculty supervisor relieves the graduate students from making difficult decisions and enforces the UMD's rules regarding attendance and test make-up in the undergraduate courses. These TA support programs were designed within the UMDs and are unique to each. Consider a Chelsea University student who stated "I found excellent instructors in the department who valued my opinions and talents in the classroom and taught me a lot about teaching practice…"

Students, as well as the departmental websites, also mentioned other professional development opportunities for graduate students occur through the institutions' Graduate Schools. These programs are campus wide and are not directed toward a specific field of study. However, these programs include a variety of opportunities for students to participate in professional development. For example, the graduate school at Preston University runs a program every semester where graduate students get to teach a higher level course under the mentorship of a faculty member as well as participate in seminars about improving teaching methods. Four other universities (Weston, Wagner, Chelsea, and Baldwin Universities) have similar graduate teacher programs, in which graduate students improve on their teaching and learn effective ways for teaching mathematics at the undergraduate level.

Academic support through departmental resources

Besides having teacher training workshops and seminars, the departments offered other means for professional growth. Students from both Preston and Chelsea mentioned the library resources that are available to them. Further, websites for three of the universities; Weston, Baldwin and Chelsea, have links to the mathematics library on their graduate resources page.

Also, included under resources for growth was the promotion of mathematical professional societies by the UMDs. These included Society for the Industrial and Applied Mathematics (SIAM), American Mathematical Society (AMS), Mathematical Association of America (MAA) or Association for Women in Mathematics (AWM). The Website analysis revealed that Weston, Preston, Wagner, and Baldwin Universities all provided links to these professional organizations within their graduate student/department pages. However, these organizations were not mentioned during the DGP interviews.

Another resource for professional growth was the research opportunities that departments provided for their students, which were not necessarily attached to the Research Assistantships. Some of these research opportunities were REGs (Research Experiences for Graduate students). These opportunities were available for first year students and were typically funded by the National Science Foundation. These REGs were for summer experience in research, and participants got to present their work at SIAM, AMS or other meetings and conferences. These opportunities were mentioned by the DGPs at Preston, Weston, and Chelsea Universities. The purpose was to expose students to mathematical research early in their graduate school career.

Students who had Research Assistantships (RAs) discussed opportunities to work with research teams (including members from other departments) as well as working with post doctorates. For example, “I was happy to meet a friendly post-doc who has been very generous with his time and gave me a research problem to work on which resulted in my publishing a paper” (Chelsea University, graduate student).

The diversity of research within a department (also an Attractant) can provide academic support for students. It allows the students the ability to explore several different topics before choosing a focus for their dissertations. Students were able to attend seminars and colloquia in different areas or take classes that explored different areas of mathematics. In other cases, students were exposed to different kinds of mathematics for the first time. For example, students that had only been exposed to pure mathematics in their undergraduate careers were able to explore some applied mathematics through course work, and then decide on an area in which they might want to conduct research. Another benefit that UMDs with diversity in research, is that students are able to find advisors and research topics that interest them. For example, one student from Preston University stated that part of the reason she stayed at Preston was because "I was happy here and had found an advisor to work with that is compatible with my personality and research interests".

However, the converse is also true. When asked about things the graduate students would change, five students from four of the UMDs (Preston, Caldwell, Weston, and Chelsea) wanted more faculty that were specialized within specific areas of research in which the students found particularly interesting.

Exam Practices

Departments with flexible and transparent exams practices provide students with a freedom to choose topics that are relevant to their studies and can be taken at a convenient time. This section addresses one of the most elemental experiences for graduate students in doctoral programs. Graduate students in all six PhD programs are required to take qualifying exams (sometimes called comprehensive exams) (Walker et al, 2008). This experience can be harrowing, stressful, and a "source of profoundly mixed messages" for students (Walker et al., 2009, p41). Based on a comment from a student on the GSOQ, the researcher closely examined the exam practices of the six UMDs based on the information provided in the UMDs web pages. The data suggests that a characteristic of many of the UMDs' exam practices includes freedom of choice of topics for exams, the availability of practice exams, and foreign language requirements.

Qualifying exams are those exams that upon passing, a student is admitted to candidacy in the mathematics doctoral program. From the GSOQ, there was one student who mentioned that the different options for qualifying exams' were a selling point in acceptance of admission to Preston University. This statement sparked further research on the qualifying exams for each of the six mathematics' departments. The researcher used UMDs' websites to find information on the various types and requirements for qualifying exams. The result is that 5 of the 6 universities offer the students some choice in what exams to take. Some universities offer more freedom than others, but all five allow the students to choose at least one of the exam topics from a selective list. The only university that did not provide the students with the freedom of choice was Caldwell University. And even this is up to interpretation, meaning that if the student wanted to pursue Computer Science (this is a computer science and mathematics department), they could substitute one of the math exams for a computer science exams. However, math students do not have any choice; they must take three exams in Topology, Algebra, and Analysis.

Preston University's mathematics department gave the students the most freedom in choosing qualifying exams. They had examinations for 13 different subjects; therefore, the exams could be tailored to the students' interests or research. The other four mathematics departments allowed students the freedom of choice in choosing the fields in which they would be tested from a smaller pool of areas.

The UMDs that provide practice exams or past exams to their students are creating open academic environments. Within each of these departments, the expectations and practices associated with the qualifying exams are available and open to the students. In other words, students are aware from the beginning what the expectations and guidelines for qualifying exams are (Golde, 1998). Along with qualifying exam choice, practice and past qualifying exams were posted on the websites for past qualifying exams can be found on four of the mathematics departments graduate pages (Baldwin, Wagner, Weston, Chelsea Universities). Although, past exams at Preston University were available through the graduate student network (see Chapter 6), they were not posted on-line. However, the pages for practice and past qualifying exams at Weston University were password protected, it seems reasonable to assume that they were posted and up to date. These four universities posted past exams and Preston University also posted syllabi for their different exam topics. Caldwell University was the only department that did not post past exams or syllabi on their public space.

Alignment of Master's and PhD Programs

UMDs in this study also support their students academically in their pursuit of doctoral degrees, by making their Master's programs related to the doctoral programs. They do this by providing doctoral students with the opportunity to earn Master's degrees with very little extra work. As a result, several students stated that they earned Master's degrees en-route to their PhDs and that it was a part of the doctoral process at their respective institutions.

In connection with Master's degrees being closely related to doctoral programs students from three universities stated that they believed it was too much of an effort to change universities after completing Master's degrees. One student felt they would have "to start over", another felt that switching would "slow you down". If one looks at the responses in connection to earning a master's en-route to a doctoral degree, then it seems that students applied to doctoral programs intending to stay at the same institution throughout their graduate career. For the students in this study, it was not common for them to switch institutions.

Students indicated (from four universities), when answering the question concerning earning a master's degree and leaving an institution, that they enrolled in doctoral programs with the intention of earning a PhD at that institution, and did not consider leaving to be an option for them. They felt that earning a master's degree was part of the PhD program and not a separate part of the program in which they were enrolled.

Graduate programs in which it is easy to continue after receiving a Master's degree give the students two viable options at the end of a master's degree. First, the student who is dissatisfied with the program and wishes to switch universities or pursue a career can leave after the Masters degree and feel like that is a viable option. Second, a student can choose to continue with their education at their current university and the transition from Masters to Doctoral programs is fairly easy (Golde, 1998). However, the students in this study stated that they enrolled in doctoral programs and the Master's degree was earned along the way.

The students that did switch gave several different reasons; prominent among them was a lack of doctoral program at their Master's institution. Moving to a university in order to pursue a PhD because their current university did not have a doctoral program was not necessarily a reflection on the environment of that Master's department. It may simply be a reflection of the student's changing goals. However, one student from Caldwell University stated they wanted to earn a Master's degree elsewhere in order to apply to and be accepted into better doctoral programs. There is no further information provided about why the student felt this way, but again their leaving the Master's institution may not be a reflection on that department's climate.

Financial aid and Academic Support

Different funding opportunities gave students a variety of experiences. The most common funding opportunities were associated with teaching assistantships. Students were able to partake in a variety of roles, from lecture assistants, graders, discussion leaders, and instructing their own sections. Prior to teaching a section, students at Chelsea, Preston, and Weston universities, had a less demanding role usually grading or leading a discussion group (DGP interviews). This allowed the students an acclimation period in their first semester and gave them time to participate in the various teaching workshops offered at their respective universities prior to teaching a section on their own. In addition to less demanding duties, at the three universities, there was a faculty member that was supervising all the TAs. These faculty members helped with class organization and administrative duties.

Office Space for Graduate Students

Another way in which the UMDs provided academic support for the students was through fostering and supporting students in providing them with office space, which can promote student to student interactions that are collaborative rather than competitive in nature. Many of the students and the DGPs discussed the importance of office space and the role it plays in creating bonds between graduate students. Along with promoting collaboration among the graduate students, the department also sponsors social activities in which both graduate students and faculty members participate.

First year graduate students at Preston, Caldwell, and Chelsea University all share a single large office. The DGPs stated that this was done on purpose to encourage the students to get to know each other, work together, and form cohesive cohorts that will support the students throughout their program, especially through the course work and exam phases.

Advisor Roles

According to the literature, advisors and mentoring can be one of the most important aspects of graduate education in terms of retaining women in STEM fields (Herzig, 2004; Lovitts, 2001; Walker et al., 2008). Therefore, it was not uncommon for students to talk about their advisors when answering the open ended questions in the GSOQ. Nineteen different responses from four UMDs (Preston, Weston, Chelsea, and Wagner Universities) addressed issues related to advisors, the roles of the advisors, and the relationships between advisors and their students. In terms of academic support, students reported a wide variety of roles of that the advisors played for them. These roles included taking students to conferences and helping them prepare for professional talks, securing funding for students, building strong relationships (both professional and personal) with advisors, offering support and reassurance when students are feeling overwhelmed, and providing the students with contacts for prospective jobs after the completion of their doctoral program.

The DGP interviews revealed how the faculty approach advising and mentoring their students. For example, all first year students at Baldwin and Preston have the same academic advisor, the DGP him or herself. The purpose of this advisor is to help them select courses, adjust to the academic program, secure funding, and locate information concerning their degrees and progress through the program. Once the student selects an advisor with whom to work, then the first year advisor is no longer necessary. However, the students and advisor may maintain personal relationships throughout the academic career of the students.

While none of the UMDs had specific mentoring training programs for their faculty, the DGPs discussed how they felt mentoring was important. They also recognize the difference between advisors for the first few years, and thesis or dissertation advisors that aid the students in writing their dissertations and conducting research. Weston's DGP stated that the most important thing was for faculty advisors to have open and supportive relationships with their students. Therefore they try to match students with faculty members in which they feel that that relationship can grow, however, they also encourage students to change advisors if there are issues within the relationship that are not conducive to learning mathematics.

Faculty Accessibility

Students frequently interact with faculty members on a one-on-one basis are during office hours for courses in which they are enrolled. It is a time when students can come to the faculty member's office and ask questions pertaining to the course material or homework. The organization of how the office hours are run is under the control of the individual faculty members. Some faculty members have an open door policy and students can come and go as they please, while others schedule appointments on an as needed basis. Also the personality of the professor can play a role in the students' experiences during office hours. For example, one female student described a memorable experience where she attended office hours and was turned away with her questions unanswered. While this is a frustrating experience, it may be limited to a single faculty member in a single course, and not representative of all here experiences with office hours. However one thing is certain, it left an impression on her. One the other hand, students often reported that the faculty are willing to help outside of class and are easy to approach with questions.

Interactions

These UMDs facilitate opportunities for interaction among its members.

In addition to providing academic support, these UMDs have created environments in which there are opportunities for interaction among the members. These include providing space and times for graduate students to interact with other graduate students, as well as creating opportunities for graduate students to interact with faculty members (especially those faculty members who are not instructing classes). There is significant overlap here with some of the early descriptors, but it is appropriate to reiterate when discussing interaction opportunities.

Office space of the graduate students

First year graduate students at Preston, Chelsea, and Caldwell all share large common offices. By sharing an office, the graduate students are in close proximity and can easily communicate with each other. This allowed the students to easily work together on homework assignments, share notes from previous courses, study for exams together, prepare for their qualifying exams, discuss teaching duties and lessons, and engage in informal social gatherings. Implications of these activities and their connection to helping students build relationships will be discussed under the final characteristic.

Colloquia and Seminars

Students valued the seminars offered at their respective UMDs, particularly those run by the graduate students. Chelsea University students generated particularly interesting comments about the seminar series. A series of particular interest is the *Women in Mathematics Seminar*. This seminar is designed to provide a "relaxed, supportive, and stress-free environment in which women graduate students, post-docs and faculty can interact" (Chelsea University website, 2009). The student responses stated that they liked this seminar and that it provided them with the opportunity to meet more senior women in mathematics, both graduate students and faculty. The students also valued the other seminars (those run by faculty) as a way to interact with faculty member within their areas of interest.

Social Events within the Department

Departmental social events may include department picnics, luncheons, or study sessions for graduate students. One departmental sponsored social event was regularly scheduled department teas. A smaller and more selective departmental sponsored event was organized events for women in the department.

Women students at Caldwell, Weston, and Chelsea Universities specifically discussed social events that involve women only groups. A Weston student talked about these events in terms of recruiting more women to the program and her experience during the recruitment weekend; "the female graduate students had a department sponsored dinner with only the female applicants who were admitted. It was a kind gesture and helped to show that the department was sincere in their efforts to recruit more women students." The students from

Caldwell and Chelsea explained events that were more a part of the culture of the department rather than recruitment tools. Both these universities have Women in Math groups that gather for seminars, luncheons, and dessert nights. Participants in these groups get to meet and interact with female faculty and older female graduate students. One woman from Chelsea explained the importance of meeting people like this, "knowing people makes me feel more comfortable with continuing my study [here at Chelsea]". Departmental sponsored social events are an important link for meeting new people and getting to know them, and can be related to the climate and general welcoming feeling of the department as a whole.

A specific type of social activity sponsored by some of the UMDs are department teas, informal social gatherings within a department in which faculty and students gather to enjoy an afternoon snack such as cookies or other baked goods and chat among the group. Department teas give both faculty and graduate students to interact with others in which they may have little interaction with during the rest of the week or day. A Preston University student stated that the teas were a memorable experience because "I have had some interesting conversations with both classmates and faculty members during the numerous department teas". It also provides an environment for introductions to be made between members of the department, specifically between graduate students and faculty. Department teas can therefore be unofficial networking sites for graduate students. In this way new students can learn about research conducted by various members of the departments, funding opportunities with different research grants, and personalities of faculty members with which they may consider working with in the future. The teas also gave opportunities for faculty members to talk to each other about the students and recommend students for research projects or opportunities with faculty members also interested in similar fields.

Department teas can be held as often as the department wishes. For example in this study, Weston University held daily teas and Preston University held weekly teas. Students from Preston University and Weston University felt that their department teas where important enough to mention as something that was memorable. Students from both universities stated that they felt the department teas were a good way to meet people, converse about mathematics with other faculty and graduate students, and to socialize with faculty and graduate students.

Common Spaces

Common spaces are those in which faculty and students can gather and mingle together. These include graduate student lounges, faculty lounges, mathematics department common rooms, break rooms, or mailrooms (if they are large enough). Common spaces allow for impromptu gatherings of graduate students and faculty. These gatherings help to encourage communications between members of the department. For a Preston University student, the break room was a place to solve mathematical problems and make “nerdy math jokes”. In other words, it was a place he associated with doing math and having fun. In some cases, the common spaces provided more home-like amenities as was the case at Weston University where students had access to hot-water faucets and the ability to make tea.

Relationships

Graduate students create opportunities for interaction and value the relationships formed from such interactions.

This section address the ways in which graduate students take advantage of the opportunities offered by the department as well initiate their own opportunities to form close relationships and friendships among themselves.

Office space of the graduate students

By sharing office space and having the opportunity to engage in a variety activities, such as working together on homework, or impromptu social events, graduate students form relationships and take advantage of the friendships formed. These relationships and friendships were something that students discussed frequently in the GSOQ. Some students mentioned these relationships in relation to their decisions to stay in their respective UMDs. For example one student from Preston University stated “there are several small groups of students that rely on each other and usually spend their ‘spare time’ together. Homework is often done in groups; however everyone is expected to pull their own weight.” The common office space for new graduate students helps students to “become very good friends with [other students]” (Chelsea University, graduate student).

Collaboration between graduate students

One way that students collaborate was during study sessions. The responses to the GSOQ revealed that students often studied for courses or exams together, and that these study sessions were memorable enough to remember and mention. For example, “there have also been some rather memorable late night study sessions” (Preston University graduate student). In other words, students try to help their fellow classmates for as long as it may take. By encouraging students to work together in study groups, the faculty have created a community of collaboration that is valued among the graduate students. Graduate students often work together who are in the same year or cohort, because these students are usually in the same courses. When the study groups got stumped on a problem or topic “any older grad[uate] student that was nearby would gladly offer help” (Caldwell University, Female Graduate Student).

However, not all students were satisfied with their early attempts at collaboration during study sessions. Three students (from Weston, Baldwin and Chelsea Universities) felt that choosing who you study with was as important as the act of group studying. Some women found that some of their male study partners could be condescending and belittling (ignoring suggestions, saying that’s easy in response to a question). Fortunately, these women found other people to spend time with, ask for help, and find support.

This level and amount of collaboration made the students feel like the environment was not built around unhealthy competition between the students in the department. Rather the competition the students did face was not promoted by the department and was in good fun. One student summed this point up nicely when she said, “There is just a good sense of teamwork among the younger graduate students. Everyone helps each other and we all strive to excel together’ (Chelsea University, Female Graduate Student).

Social activities outside of the department

One way in which graduate students from bonds and build relationships is through social events and activities outside the department. One Preston University Male student stated that the "graduate students are pleasant, sociable who have more to their lives than long hours studying math". This statement was repeated in many of the responses, indicating that the students believe their lives are "balanced" and involve other activities besides studying mathematics to the exclusion of all else. Students from all six UMDs reported that they participated in various social activities that were organized by graduate students. Some examples included; potluck dinners, intramural sports, skiing trips, game nights, and attending sporting events together.

Informal mentoring of graduate students

Informal mentoring of graduate students refers to the passing of knowledge about the department from more senior graduate students to prospective or new students. This information is essential to the new graduate students' ability and comfort level to becoming participating members of the department's culture (Golde & Walker (Eds.), 2006). Further, a mentor is an "experienced person in an organization or institution who trains and counsels new employees or students" (In *Oxford English Online Dictionary*, retrieved October 19, 2009, from http://www.askoxford.com/concise_oed/mentor?view=uk).

During recruitment weekends, prospective students met with older students who shared information about the department and set the tone for the graduate student relationships in the future. Before students attended their first semester, more senior graduate student gave them advice about courses, recommended housing, and gave tours of the area (Preston University, Female Graduate Student). Further, the DGPs stated that they knew these informal mentor and mentee relationships existed in the student body and to some extent they encourage them through their encouragement of collaboration and building relationships among the graduate students.

Summary

The five characteristics that described the six UMDs in this study were related to the department or institution in which the UMD was housed, and to the graduate student population. Due to the fact that these six UMDs are different in terms of their graduate student numbers, geographic location, and types of degrees offered makes generalizing these characteristics difficult. However, some conclusions might be drawn about departments with similar environments. First, all of these departments foster relationship building between their graduate students through encouragement of collaborative work. The UMDs also provide a variety of different types of academic support that range from professional development opportunities to advising and mentoring of graduate students.

An important fact to note is that none of the five characteristics is completely independent of the other four. Many of the descriptors were used to describe multiple characteristics. It is possible that these five characteristics have to co-exist in UMDs that wish to support all their students as well as achieve and maintain gender diversity.

The next chapter is going to focus on the descriptors and characteristics which were enhanced by the case study. The final chapter will address how these descriptors (see Table 24) are related to the Communities of Practice Framework.

CHAPTER 5: CASE STUDY OF PRESTON UNIVERSITY

The purpose of this chapter is to answer the following research question:

> *How do the characterizations of the collective case of University Mathematics Departments influence the graduate students and faculty members' experiences of their community within a single Mathematics Department?*

For this case study, a single University Mathematics Department (UMD) that has a relatively high percentage of women graduates was studied. Preston University's Mathematics Department was chosen because they had the highest number of students answer the Graduate Student On-line Questionnaire and they were represented in all but three of the descriptors describing the characteristics of the collective case of UMDs as described in Chapter 4.

This chapter begins with an introduction which provides contextual background for the in-depth case study. The chapter then continues with two additional goals. First, it is necessary to describes new characteristics and descriptors which were developed during the data analysis of the case study's faculty and student interviews. Second, in order to portray how the characteristics and descriptors impacted graduate students and faculty members' daily lives in the department, two vignettes in the style of narrative essays are presented. Narrative essays will help tell the story of the UMD through the perspective of members of Preston's Mathematics Department.

Introduction of the Case: Preston University

Preston University is located in the Southeast region of the United States in an urban setting. The campus has approximately 34,000 students, including 8,000 graduate students. The university student body consists of 42% women and 58% men. Further, Preston

University is ranked nationally and internationally for its academic programs and research opportunities for students. These acclamations and the network of public and private partnerships consistently earn Preston a spot of one of the nation's top research universities. Preston University shares distinctive characteristics with other institutions: broad academic offerings, emphasis on public service, national and international activities, and large-scale research and extension programs (University Website, 2009).

The mathematics department is housed in a building within easy access to most of the rest of the campus. The building was built in the early 1960s, and houses several other departments. Most offices of the Mathematics Department faculty and staff are housed in this building, but the graduate student offices are housed in various other buildings throughout the campus. The Mathematics Department has more than 60 tenure-track faculty, approximately 200 graduate students, and approximately 200 undergraduates majoring in mathematics. The following tables (Tables 25 and 26) show the enrollment of students in the Mathematics Department at the time of the study. The tables are divided by degree level and race and degree level and gender (University Planning and Analysis Website, 2009).

Table 25: Mathematics Department Enrollment Totals by Degree Level and Race

Degree Level	Total	White	African American	Native American	Asian	Hispanic	Not Reported	Inter-national
Undergraduate	183	139	20	0	10	6	5	3
Graduate	192	118	11	1	4	4	4	50
Total	375	257	31	1	14	10	9	53

Table 26: Mathematics Department Enrollment Totals by Degree and Gender

Degree Level	Total	Women	Men
Undergraduate	183	71	112
Graduate	192	85 (44.3%)	107 (55.7%)
Total	375	156	219

New Characteristics and Descriptors

Recall that in the collective case of six UMDs, the analysis of responses from the Graduate Student Online Questionnaire (GSOQ), Director of Graduate Programs (DGP) interviews and the websites uncovered five characteristics of these UMDs that have high percentages of women graduating with doctorates in mathematics. Those characteristics as described in Chapter 4 were:

- *Graduate students are attracted to these UMDs for a variety of personal and universal reasons*. [Attractants]
- *These UMDs provide a welcoming and diverse environment for graduate student success*.[Environment]
- *These UMDs provide different structures for supporting their graduate students throughout their academic careers*. [Academic Support]
- *These UMDs facilitate opportunities for interaction among its members.* [Interactions]
- *Graduate students create opportunities for interaction among themselves and value the relationships formed from such interactions.* [Relationships]

In addition to these five characteristics, the analysis of the case study data of Preston University indicated that additional characteristics and descriptors as well as some enhancement of the original five needed to be in the results. Listed below are the enhanced or new characteristics, followed by Table 27, listing in detail the additional descriptors. A discussion of the new descriptors will follow the table.

- *Members of the departments (students and faculty) are attracted to these UMDs for a variety of personal and universal reasons*. [Attractants]
- *This UMD provides a welcoming and diverse environment for graduate student and faculty success*.[Environment]
- *Faculty members create opportunities for interaction among themselves and value the relationships formed from such interactions*. [Relationships – Faculty]

Table 27
New Characteristics and Descriptors from Case Study

Characteristic	New and Enhanced Descriptors from the Case Study
Attractants	Faculty feel they have a certain amount of freedom
	Faculty like the applied aspect of the department
	Students felt that this department would allow them to leave their research options open
Environment	Open and Supportive faculty – not only in terms of supporting students but in terms of supporting each other
	Family Friendly faculty and department
	Faculty enjoy working with students and helping them through transition stages
	Faculty members feel that they have a degree of freedom in pursuing their own research interests, collaboration with others and in choosing publications.
Academic Support	Personal investment in students before the start of the new semester
	Faculty engage students in professional development through internships, conferences and professional communication skills
	The UMD provides students with teaching and research mentors (not always the same person)
	Students are able to become involved in mathematical research early in their graduate school careers
Interactions	Many opportunities for collaboration among faculty members (both in and without the department)
	Junior Colleagues – through engaging students in research and supporting them through their research
Relationships – Faculty	Faculty mentoring – senior faculty mentoring new or junior faculty
	Office space – location of offices affects faculty feelings of collegiality
	Faculty engage in unofficial social events, lunches, dinners …

The faculty and graduate student interviews from Preston University supplemented the descriptors and characteristics from the six UMDs nicely. The faculty provided a different perspective than those of the graduate students, and Preston's graduate students were able to discuss their perceptions and experiences in greater detail. The faculty discussed both relationships among the faculty and relationships between the graduate students, enriching the descriptors to include a new population. The following section discusses new or enhanced characteristics and their descriptors, from the faculty perspective.

Attractants. Graduate students were attracted to their UMDs for many different reasons; the same was true for the faculty at Preston. Faculty expounded on reasons why they choose to stay at Preston University. Four of the eleven interviews revealed that the faculty felt they had a great deal of freedom within the department. This freedom was discussed in terms of pursuing different roles and career paths within the department during different stages of their career, the freedom to pursue different types of research in the department, including research in interdisciplinary fields, and the freedom to publish in journals that are related to the research being conducted rather than specifically mathematics research journals. Further, this notion of freedom was linked to the large diversity in research fields being explored by the faculty and choices of different colleagues with which to collaborate or discuss similar research. Another related attractant is that Preston is a mathematics department with a large emphasis on applied mathematics, and a large number of faculty exploring those areas.

Academic Support. The faculty confirmed in their interviews that they provide their graduate students with a variety of academic support structures. Primary among these is the professional experiences and development that they offer their students. Most of the students gain these experiences through individual contacts with their advisors and mentors. As part of their mentoring roles, faculty discussed the importance of taking students to conferences, giving them opportunities to present their work, introducing them to other professors interested in their fields, teaching them how to do research and how to communicate that research, and helping students find good questions to ask and solve. Many of these roles allow the faculty and students to collaborate on different levels. Faculty members also try to find and maintain the funding that their students receive.

In addition to the academic support outlined in Chapter 4, the graduate students at Preston University provided insight in to the fact that they all had an opportunity to become involved in mathematical research early. The research ranged from being mentors to undergraduates during the summer enrolled in REU programs, students involved in Research Experiences for Graduate students in their first year, and being able to work on research projects with faculty members. These students felt that the research opportunities allowed them to see what mathematics research involved, as well as getting them excited about continuing research in their chosen areas.

Environment. The students from Preston University described the faculty as open and supportive of all its students. The faculty stated that they enjoyed working with students, and helping through the different transition phases of the graduate school process. These phases included coursework (for those students who found their advisors early), the qualifying exams, and helping the students to become researchers during their dissertation phase.

The faculty were also supportive of each other. They showed this supportiveness through mentoring where more experienced faculty mentor younger faculty during their first few years, helping them with their teaching assignments, research, and grant writing. In addition to mentoring, faculty do not feel restricted by their department in terms of research, collaboration opportunities, or pursuit of different career paths within the department.

Only two female interview participants had small children at home; one faculty member and one graduate student. Both of these women mentioned the family friendly nature of the department. Both in terms of supporting graduate students and faculty with small children and supporting those who choose to start families. The faculty member relayed her experiences of being pregnant in the department. The administration and faculty were extremely supportive of her. The graduate student had two small children. Her schedule was often dictated by their school calendars. Her advisor helped her to balance school and home, by allowing her to work from home during the weeks when her daughter was not in school. Further the advisor was understanding and supportive when the graduate student needed to bring her daughter to campus. The student stated that needing to make adjustments to her work schedule or bring her children to campus has “never been a problem with my advisor, he is unbelievable supportive of my family” (Female graduate student, Preston University).

Interactions. The faculty interviews showed that the department and faculty have many opportunities to collaborate with each other, with faculty in other departments, and with their students. The level of collaboration, however, was dependent on the faculty members themselves. Some described lots of collaboration and group research as part of their individual fields, while others preferred to spend more time working alone. This range was also evident in their relationships with their graduate students. Faculty members wanted their students to learn to become individual thinkers and researchers, but some faculty members also stressed the importance of working with teams of researchers, and provided these opportunities for their graduate students.

In addition to working with each other, the graduate students felt that the faculty treats them like junior colleagues; engaging them in research and supporting them through that research. These professional relationships illustrate a variety of ways in which the faculty fosters those relationships through the academic support of the graduate students.

Relationships. Similar to the graduate students, (as discussed on Chapter 4), faculty created opportunities for building maintaining meaningful relationships among themselves. They build these relationships initially through the mentoring of new faculty. This provides the junior faculty members the opportunity to discuss concerns and learn the informal nuances of the department. The location of the faculty offices also helped to build relationships. Many of the faculty were in offices located close together, this provided opportunities for impromptu meetings or informal discussions. However, faculty that were not in this general area felt isolated from the rest of the department and did not have the easy access to other faculty members, graduate students, or staff. Having centrally located offices also helps faculty members participate in unofficial social events, such as having lunch together, or dining out after evening seminars.

Conclusions about new Characteristics and Descriptors. Students and faculty members who participated in the interviews were generally happy with the department. They felt that the department provided them with a climate in which they could be supported and provided with the structure to succeed. The faculty were invested in the students. At the same time, the students felt like specific faculty members are invested in them. The mentoring between faculty and graduate students contributed to the feelings of being supported. Also, the graduate students appeared to be invested in each other. The students often discussed working together to complete homework assignments and to prepare for exams, both class exams and qualifying exams. The collaboration went beyond students enrolled in the same courses to include students previously enrolled in those courses willing to help newer students navigate the content. In order to tie the collective case study characteristics and the Preston's Case study together, Table 28 represents all characteristics and descriptors, original and new, found in the study.

Table 28
Characteristics and Descriptors for Preston University

Characteristic		Descriptor
Attractants	**Personal**	Program recommended
		Geographic location
		Family obligations/responsibilities
		Limited options in graduate programs
		Satisfaction with choice of program
		Faculty feel they have a certain amount of freedom
		Faculty like the applied aspect of the department
		Students felt that this department would allow them to leave their research option open
	Universal	Diversity of research
		Size of department
		Reputation of university and/or department
		Faculty areas of research
	Both	Financial Aid
		Recruitment
Environment		Faculty value success of students
		Friendly and welcoming
		Perceptions of gender issues
		Gender diversity among faculty and students
		Open and supportive faculty -- both terms of supporting students and faculty
		Family Friendly faculty and department
		Faculty enjoy working with students and helping them through transition stages
		Faculty members feel that they have a degree of freedom in pursuing their own research interests, collaboration with others and in choosing publications.

Table 28 (continued)

Academic Support	Colloquia and seminars [a]
	Teaching and professional development (voluntary and in-voluntary)
	Resources for growth, i.e. Library
	Exam practices
	Alignment of Master's and PhD
	Financial aid [a]
	Diversity of research [a]
	Office space of the graduate students [a]
	Collaboration between graduate students [a]
	Advisor role [a]
	Faculty accessibility [a]
	Personal investment in students before the start of new semester
	Faculty engage students in professional development through internships, conferences and professional communication skills
	The UMD provides students with teaching and research mentors
	Students are able to become involved in mathematical research early in their graduate school careers
Interactions	Office space of the graduate students [a]
	Collaboration between graduate students [a]
	Colloquia and seminars [a]
	Social events within the department
	Advisor role [a]
	Faculty accessibility [a]
	Regularly scheduled department teas
	Common spaces
	Many opportunities for collaboration among faculty members (both in and without the department)
	Junior Colleagues – through engaging students in research and supporting them through their research
Relationships (Students)	Office space of the graduate students [a]
	Collaboration between graduate students [a]
	Social activities outside department
	Informal mentoring of younger students from more senior students
Relationships (Faculty)	*Faculty mentoring – senior faculty mentoring new or junior faculty*
	Office space – location of offices affects faculty feelings of collegiality
	Faculty engage in unofficial social events, lunches, dinners …

Note: [a] -- descriptors may appear in more than one characteristic New or enhanced characteristics are Italicized

Vignettes

This section reports more of the results from the in-depth Case Study through a narrative essay (Baker & Brizee, 2007). Narrative essays tell a story usually from a specific point of view. I choose to represent the data in the style of a narrative essay because it would best bring to life the elements of the Communities of Practice, and how they are interconnected in the daily lives of the department's members. Further, the narratives will illustrate the findings in such a manner that the reader will get a feel for what the community may look like. These particular narrative essays are from the perspective of a graduate student and a faculty member. The student narrative essay is written from the viewpoint of a representative graduate student in Preston's UMD. The second narrative essay is written from the outlook of a faculty member who is also representative of faculty from Preston's UMD.

Student Vignette

Introduction and Outline. The following description through story telling is an account of Terry's experiences as a graduate student in Mathematics at Preston University. The story is based on the data collected from 42 online questionnaire responses, 16 graduate student interviews, 5 new student questionnaire responses, and 11 faculty interviews. Additional characters will be woven into the story for the purpose of illustrating specific experiences that may be relevant to a specific subset of the graduate student population. Terry's gender will remain ambiguous because the department operates as a whole and everybody's experiences and perceptions are crucial to the environment and atmosphere within the department; thus gender seems to be a less obvious factor in representing the graduate students' experiences.

During the narrative, elements of the vignette which are related directly to the characteristics outlined in Table 28 are denoted with an *. Appendix Q shows which interviews contained elements from each of the characteristics and its descriptors. However, there are elements in the vignette that are not cited in this manner. I occasionally used personal experiences which were conveyed in the interviews, but were not considered in developing the characteristics of the UMDs, as a foundation for developing a story line that grounds the vignette in reality.

Terry's Big Day. Terry, a doctoral candidate in mathematics at Preston University, is preparing the last official requirement before graduation. Five years of graduate school, countless homework sets, qualifying exams, late night study sessions, and meetings with advisors has all led to one big day, the dissertation defense. The following vignette is an account of Terry's experiences, feelings, and perceptions leading to this day.

The Night Before. As I lay in bed going over my presentation notes for tomorrow, my mind wonders over the past five years and I know that the dissertation defenses at 9:30 am will be the culmination of all my hard work in graduate school. It feels like a lifetime ago that I first stepped on the campus. Most of my cohort will graduate with me this May. Has it only been five years? What if tomorrow does not go well, what if I forget what I am supposed to do? I know that I should get some rest and stop worrying about tomorrow morning's presentation, but I find sleep a remote possibility recalling my experiences here at Preston; triumphs and disappointments, concerns and friendships.

Undergraduate Influences and Experiences: Six Years Earlier. It was fall on campus again at Sunny University, everyone had returned with a sudden onslaught I would not have believed as a freshman. As a senior, I had come to appreciate and take time to notice how the trees were a riot of color that painted the limestone buildings with splashes of yellows, reds, oranges, and browns. I was on my way to meet with my academic advisor, Dr. Wilson. My agenda for the meeting was to discuss graduate school again. Last spring Dr. Wilson had started the conversation and suggested that I get some outside experience doing mathematical research. He suggested that I apply to several Research Experiences for Undergraduates (REUs)* and see what happened. The result was that between my junior and senior year, I went to California to work with a group from a University*. What an amazing experience that was. I learned so much about mathematical research and what you could do with a mathematics degree*. I got to meet new people that are interested in mathematics at different of levels*. I worked with other undergraduate mathematics and science students, graduate students, post docs and professors for a 10 week period. The project was engaging and exciting. We spent quite a bit of time discussing my options for graduate school. Those conversations encouraged me to really start thinking about my future career. I applied for another REU for the following summer. All in all the REU experience made me feel more confident and excited about attending graduate school, still it was a big decision, and one that needed to be made soon.

My list of questions for Dr. Wilson consisted mainly of determining if graduate school was the right option for me*. I knew that I loved math* and had always been a top student in all my math classes. What do you do with a math degree, besides go to graduate school or teach? At that point I did not think I wanted to teach high school. Dr. Wilson seemed to think that I would do really well and had some university recommendations* for me; his reason for the meeting today.

Applying to Graduate School. Graduate school it was! During our meeting, Dr. Wilson and I weighed the options of graduate school versus job market. I decided that graduate school was going to be the best way for me to achieve my career goals*. I thought that I wanted to work in industry as a mathematician.

After I had made the choice, the next big question was where to apply and where to go. Questions considered: what type of school did I want to attend, was location important to me*? Dr. Wilson said that funding * can be offered to first year graduate students as a way of attracting them. What about the reputation* of the school or department? Would I be accepted at the top schools? Facts that may be important in my decision: I like Sunny University (my undergraduate institution), because as a small liberal arts college it had offered me a unique experience over the last few years. I knew the undergraduate students and professors in the mathematics department. But I did not take all the classes that I wanted to. Being from such a small school, I knew that I might not be as prepared as students from larger schools. Over the next few weeks, my roommate (who is also applying to graduate school for mathematics) and I were researching the recommendations from our advisors* and choosing which schools to apply to …

Acceptance. Yeah! I was accepted to two of the seven schools in which I applied, and waitlisted at a third. Preston University and Reese State University invited me to attend their annual recruitment weekend* in February. In addition, Preston offered me a Teaching Assistantship*; the only school to do so.

The recruitment weekend at Preston was an enormous amount of fun*. I attended a couple of different seminars*, in which graduate students and faculty talked about their research, most of which I did not understand. All of the prospective students met with the Graduate Program Directors*, took a campus tour, and went to dinner with the current graduate students*. The dinner with the current graduate students sealed the deal for me*. The students were normal and social. They had lives and hobbies outside of mathematics; they were a fun and friendly bunch of students and provided us with a student's perspective of the department and the graduate programs. I did not remember much of the advice after a few hours of meeting prospective and current students. However, the feeling which I left with was; "I could fit in here. I like these people."*

A few weeks later, I committed to Preston University. They gave me the only funding package*, the geographic region was nice*, and the people were open and friendly*. A few days later I got an email from the Director of Graduate Programs* providing some basic information and letting me know to contact him if I had any questions. Boy, I had questions. Both the DGP and the graduate secretary were more than helpful in answering those questions. The DGP also helped me organize and select courses for my first semester*.

My first years. My first semester was very difficult. I felt under prepared for my courses, and enrolled in difficult courses. However, I made new friends with the graduate students in my office*. Almost all of the first year students, and quite a number of the second years were all located within one large office*. This large office provided an amiable environment* for making friends and learning mathematics. I found within the first few weeks that if I was having trouble on my math homework, I could ask graduate students in my office*. They were more than willing to help*. Eventually, we formed a study group* that met on a regular basis to talk about the homework assignments and study for exams. After a difficult day of studying, we might all go out to dinner, or have a pot luck dinner at someone's house*. Not everybody worked in groups. Maris, a graduate student in my Abstract Algebra class, only showed up on test days. I don't think he worked with anybody, and mostly kept to himself.

I have not even met all of the graduate students. Some students are located in different buildings across campus and are already working with their research advisors*. A few students that were members of my cohort, meaning that they started the same time as me, already had master's degrees, and did not take a lot of classes*. I saw Holly the other day; she earned a Master's degree at a different university. We talked for a few minutes and she said that she had not gotten to know very many students*, but that she was enjoying working with her advisor*, the post-doc on the project*, and the other graduate students that work with her advisor. She also got a research assistantship and found an advisor when she arrived on campus*. That was lucky.

It took me awhile to find a dissertation advisor*. I had an idea that I wanted to study applied mathematics with connections to biology. Older students provided lots of advice on how to find an advisor*. Some of them told me to find a faculty member that you could work with instead of pursuing a research agenda. They said to, figure out what your desires are in an advisor and then look for a person that can do those things, trying to match your personality with theirs. They also advised me that, research funding is not necessary, as you can work on your research and continue to be funding on a teaching assistantship. I remember that sometimes faculty members would offer research positions to students that they had in class or knew were interested in their work.

I noticed that some of the second years started studying for their qualifying exams toward the end of the spring semester. Preston has 13 different qualifying exams* that you can choose from. The schedule is fairly flexible too*. You can take exams after your first year and second year, depending on when you complete your sequences. It also allowed me to tailor my course work to my research interest*. I took the first exam in the summer after my first year, and then took the second and third a year later. This completed my requirements for a Master's degree*.

There was so much to accomplish in those first few years. In addition to course work, I wanted to be involved in research*, attend the graduate seminar*, and complete my teaching duties*. Since I had been involved in REUs as an undergraduate, I got to mentor the undergraduate students who participated in the REU at Preston over the summer*. That was fun! I also was able to work on a small research project with Dr. Ho that involved computer models of biological aspects of the human body.

The first year of my Teaching Assistantship was not too time consuming*. We had an orientation to teaching prior to the first week of school*. I was a lecture assistant and grader for the first year. This was especially nice, because it allowed me to settle into the graduate school routine without the additional stress of teaching my own class. The TA coordinator, Dr. Clipper, was excellent*. He organized all the TAs and made sure that there were no problems, as well as handled issues with students*. My second year, I got to teach my own section of Calculus I. Teaching my own class was more time consuming, because I had to make lessons and make sure that I covered all the material in the course syllabus. In addition to teaching, some of my friends, received extra funding from a grant*, which awarded them extra money for being a minority in a graduate program*. They were surprised and excited by the extra funding. They did not have to teach the second semester and could start thinking about exams.

Life after Qualifying Exams. After my exams were over, I began working with Dr. Ho on more intense mathematical research, which could serve as a dissertation*. I had continued to work with him after the first small research project. We have an excellent relationship*. He was always friendly* and I could tell that he cared about helping me prepare for my career and become a good researcher*. First, he helped me prepare several talks* for the bio-mathematics seminar in which I presented for fellow students and faculty members. We were able to transforms those talks into conference presentations*. Dr. Ho spent considerable time helping me prepare a CV for my job search*, practicing interview questions and techniques, and helping me improve my public speaking. Further, I presented at several of the seminars* for my research group over the last couple of years. This really improved my research presentation skills and I had great discussions with other graduate students and faculty members. Wow, I have been busy.

Unfortunately, my contact with graduate students started to dwindle. In the last year I have had a lot less interaction with the members of my original cohort, or other graduate students. We are all so busy working on our own research and not in class together. There is still the occasional party or get-together*.

Ending. My defense is in a couple of hours. I have not slept a wink. My friends will be there to support me*. My Preston experience has been fulfilling and challenging. I know that I will continue to recommend* the program in the future to prospective graduate students. In the mean time, I am looking forward to continuing my career. I have applied to many different jobs in a variety of fields, looking for the best match for me. However, most of my applications were sent to small liberal arts colleges, where they focus was on teaching and students. Although some of my applications were also sent to jobs in industry where I would be working with a team of people.

Faculty Vignette

Introduction and Outline. The following description through story telling is an account of Dr. V's experiences. Dr. V is a tenured faculty member in Mathematics at Preston University. The vignette is based on the data collected from 11 faculty interviews, 16 graduate student interviews, 42 online questionnaire responses, and 5 new student questionnaire responses. Additional characters will be woven into the story for the purpose of illustrating specific experiences that may be relevant to a specific subset of the faculty population. Dr. V's gender will remain ambiguous because the vignette is a compilation of both men and women's experiences and perceptions within the department. Elements of the vignette which are directly related to the characteristics outline in Table 28 are denoted with an *. Appendix Q shows which interviews contained elements from each of the characteristics and its descriptors.

Dr. V, a tenured faculty member in mathematics at Preston University, is preparing for a typical day, which includes elements of teaching, research, mentoring, and service to the department. The faculty vignette is designed differently from the vignette about the graduate student. Terry reflected on all of her time spent at Preston University. Dr. V only reflects on a single day in which he/she engages in a variety of activities related to being a faculty member in Preston's Mathematics Department. The following vignette is an account of the experiences, feelings, and perceptions which may occur in a typical day of a faculty member at Preston University.

Teaching. Hmmm, let's see, what is on the schedule for today.

910-955 am	Class MA 5150
1000-1100 am	Office Hours
1200-200 pm	Research meeting with Dana
300-400 pm	Seminar

Not much time for me I see. I will have to see if I can work in time to review the article for The College Mathematics Journal that is due this week. Reviewing manuscripts can be very time consuming. But it really is a major part of being a research mathematician. And I sure do love the fact that this department is so supportive of me to pursue my own research interests and the flexibility I have in choosing the sources for publishing my work. My colleagues have published some of our collaborative research in outlets other than mathematics journals. This is an important factor, since our work is equally important in the bio-medical fields as well as in mathematics.

I should go to class. I have approximately 20 students in my graduate course, most of them are first and second years. When I arrive to the room many of them have their coffee in hand, are grouped together chatting about that one problem I gave them that I know would stump them! They seem eager to learn, and I am so glad they work well together. I always tell them that it is important they learn to work together, in addition to learning the content. During class I explain to them that mathematical research in the applied fields consists of collaboration with members of the mathematics department as well as faculty and students in other departments. Therefore, I explain, they have been assigned to work in group projects as part of the groups for this next big project.

After class, I stop by the vending machine for a snack and return to my office to make myself available to the students. Not all students come to scheduled office hours. A few prefer to email questions or schedule other times to meet. This works alright, since I have an open door policy. Students, both from class and my advisees, are welcome to stop by and ask questions. Today only a few trickle in for quick questions, and I actually am able to start reading that manuscript I am reviewing.

Advising. I have been working with Dana for several years now; we are having lunch together at one of the small cafes just off of campus. We are going to discuss her current research and possible publication opportunities associated with it. My research team also has a post working on it, and the post-doc and Dana get on very well. They spend time together working on the project. Sometimes, Dana spends more time talking to the Post-doc than to me about the research. The two of them have presented at our seminar. After lunch the three of are going to sit down together and talk about where we want the research to go from here.

Over the years, Dana and I have spent considerable time together, discussing research, working on publications, and planning her future. I believe she has come to see herself as a junior colleague in the department as she has matured and gained experience. I look forward to seeing and being a part of her transition into her career.

It has been fun watching the evolution through the graduate career into a researcher. Dana came to me at the end of the first year of course work, looking for a research project for the summer. I was able to provide an opportunity, which involved some of the REU students over the summer. Dana was their graduate mentor, and worked on modeling some data which my research team had gathered. In the fall, I wanted Dana to continue the work we had started over the summer, but did not have funding immediately available. Instead, Dana continued to work as a Teaching Assistant, participate in our weekly seminar, and continue the research at a reduced paced in addition to course work. After Dana's exams were complete (and one of my students graduated) I was able to find a little bit of funding. In addition to extra funding, Dana and I are completing professional development through the graduate school. This professional development has students think about teaching college and receive some teacher training; the students then get the opportunity to teach some higher level courses, giving them extra experience. In other professional development, I try to help Dana meet important people in the field at conferences, or through our research. Our group has several contacts in the local community. I do not instruct Dana specifically on the type of research that should be conducted, rather I try to guide the research and ask questions that encourage critical thinking and work on improving research skills.

Seminar. After meeting with Dana, I had some time back in the office where I made some notes from our meeting about where the research should go from here. I am going to meet with one of my research mentors and see what they think and if there are any big ideas that Dana, the Post-doc and I are missing. Having a research mentor allows me to discuss my thoughts about the research and bounce ideas around. Then, I continued working on the manuscript review; I am hoping to complete it before the afternoon seminar.

I really enjoy these seminars. I am able to keep up with the types of research my colleagues and their students are doing. Also, the seminars allow for conversations between graduate students and faculty in a non-threatening environment. We are able to discuss research and share ideas in a friendly and supportive manner. After the seminars, several of the faculty go out for dinner or drinks. These dinners often follow up on conversations begun in the seminar, but frequently involve discussing other aspects of departmental life, such as teaching, or graduate student mentoring.

It has been another long and fulfilling day. Tomorrow, I will spend working on my research, and hopefully finish reviewing that article.

Conclusions

Students and faculty from Preston University describe positive and nurturing experiences that allow them to build meaningful relationships among each other, and between the two populations. The graduate students are satisfied with their experiences, and often stated that they would recommend the program to other prospective students. Many of the students shared similar experiences as undergraduates and graduate students. This suggests that the students already have commonalities when attending graduate school, and they are able to build relationships based on these commonalities.

Faculty feel that the environment is supportive in terms of their own research and in helping student become researchers and teachers. They try to engage the students in research and support them through questioning and guiding techniques, often taking a personal investment in the students.

Although this chapter specifically was about Preston University, graduate students in all six UMDs have similar experiences in relation to the characteristics described in both Chapter 4 and possibly Chapter 5. I hypothesize that from the graduate students' perspective that case studies of any of the six would yield similar results, noting that small differences may occur between departments.

From the faculty perspective, however, it is much harder to generalize to the other five UMDs. This is due to the fact that the faculty demographics in terms of gender and number of faculty vary widely between the six departments. It may be possible to generalize between departments that are relatively the same size and demographic nature. For example, Preston and Chelsea may have similar characteristics among the faculty because they are both large departments with approximately 22% (University website, 2010) and 15% (DGP interview) women tenure track faculty, respectively. Because of these similarities, it is possible to at least consider that the climates of the two departments would be similar. However, sense climate and community are largely based on the participation of the members within the department.

When departments achieve a critical mass in terms of underrepresented groups, the environment of the department begins to change (Monroe et al., 2008). In departments that have few women tenure track faculty, in would be difficult to draw parallels between those departments and Preston's. This issue of climate differences in departments with fewer women leads to questions about community within those departments. Does the faculty community differ depending on the number of women? Does the number of women affect the climate and community aspects within the graduate student population? The next chapter is going to examine how the characteristics and descriptors of the collective case study, and Preston's case study are related to the three aspects of the Community of Practice framework (Wenger, 1998; Wenger et al., 2002).

CHAPTER 6: CONNECTIONS TO THE COMMUNITY OF PRACTICE FRAMEWORK

According to Wenger, McDermott & Snyder (2002), Communities of Practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4). Based on this definition, UMDs may operate as Communities of Practice. First, UMDs consist of people who "share a passion about a topic." Faculty and students choose to become members of UMDs because they enjoy mathematics and want to engage at some level in scholarly work in the field. For example, a graduate student explains that part of his motivation for pursuing a mathematics PhD is that "I have a sincere interest in the material" (Preston, Male, GS interview). He was not alone in expressing a simple love of the field and topics studied. Another student explains that as an undergraduate, she double majored in computer science and mathematics, eventually choosing mathematics because "I was enjoying math, and I didn't want to do computer science any more" (Preston, Female, GS interview).

Second, students and faculty "deepen their knowledge and expertise in this area." In the case of students, they are learning graduate mathematics content and participating in mathematical research at a new level. Several students participate in Research opportunities for Graduate students during their first year at the UMD. For example through a "women in mathematics research seminar, the students give talks to one another about their research" (Chelsea, DGP interview). Faculty are conducting research in their areas of specialty that add to knowledge of the field and graduate students are apprenticing in scholarly research and teaching. In other research seminars, graduate students and faculty participate in both presenting research and through interactions as a group discuss the research (Caldwell, Preston, and Weston, DGP interviews).

Third, the members of the UMD are "interacting on an ongoing basis". Faculty and graduate students have the opportunity to interact among and with each other in a variety of settings, including in the classroom and in conducting research. In reference to graduate student interaction, one student states "there are several small groups of students that rely on each other and usually spend their "spare time" together. Almost anyone is willing to give advice when needed and homework is often done in groups" (Preston, Female, GSOQ). Fifty (out of 146) students from all six UMDs stated that the collegiality between the graduate students and faculty is an important factor in their decisions to remain at their current universities after completing a Master's degree (GSOQ).

This chapter will answer the research question:

> *How do the characteristics of a graduate mathematics department that graduates a large percentage of women best embody the three aspects of a Community of Practice?*

Results are based on the following data sources: a) open ended questions from the Graduate Student On-line Questionnaire (GSOQ), b) Director of Graduate Program (DGP) interviews, c) Universities Websites, d)the Preston University case study, and e) the characteristics and descriptors defined in Chapters Four and Five (Tables 24 and 27). The chapter also calls upon the literature on the Communities of Practice Framework (Wenger, 1998) and explores how each of the characteristics and their respective descriptors are related to the Communities of Practice. This analysis and connection to the Communities of Practice framework is based largely on the researcher's interpretation of the Communities of Practice that have been discussed and negotiated with faculty advisors. Each of the characteristics is going to be discussed in reference to the element of the Communities of Practice in which it is most prevalent. The descriptors were not placed in the diagram according to their characteristic, rather it is how they seemed to be grouped together that is interesting and show how the characteristics can relate to the Communities of Practice.

Community of Practice Connection

Figure 9 is a modified representation of a traditional Communities of Practice diagram and shows how the different characteristics and their respective descriptors are related to the three Communities of Practice elements. The design of the figure is important for understanding the Communities of Practice as outlined by Wenger (1998) and Wenger et al., (2002). Figure 8 illustrates the three aspects of Community, Domain, and Practice, and their relation to each other. The figure represents a "Venn" diagram without the interior lines.

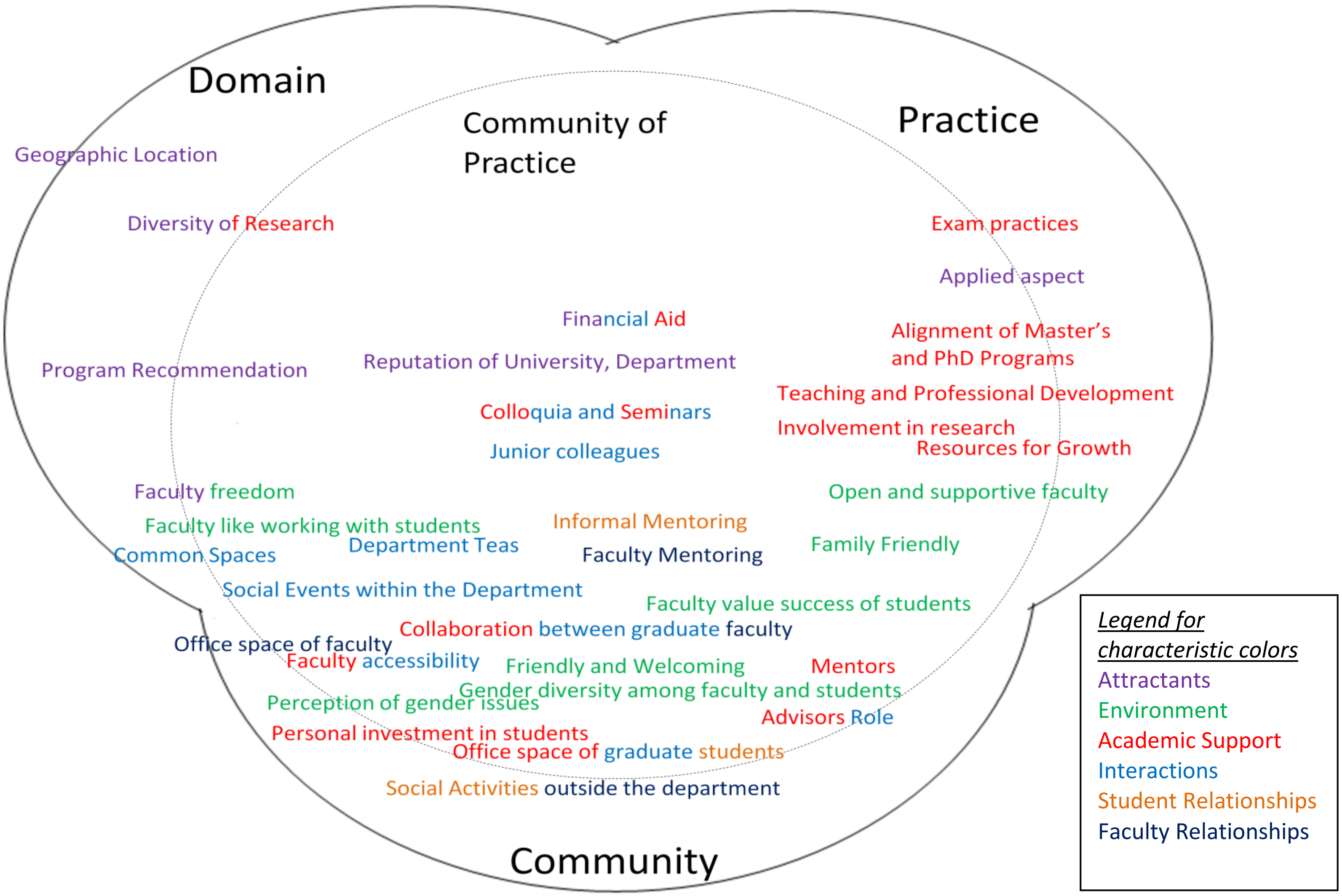

Figure 9: Graduate Mathematics Department Community of Practice

Figure 9 is a modification of a traditional Venn diagram (see Figure 10), in that the overlap regions tend to be "small" in comparison to the whole figure. In contrast the overlapping area in Figure 9 is much larger consuming much of the diagram. One reason for such a large area is to highlight the importance of each of the descriptors and show how the work simultaneously to shape the different elements and the Communities of Practice in its entirety. In addition to creating a larger overlap, the purpose for taking out the interior lines is to show that the Domain, Practice, and Community are much more fluid and dynamic than a traditional Venn diagram would depict.

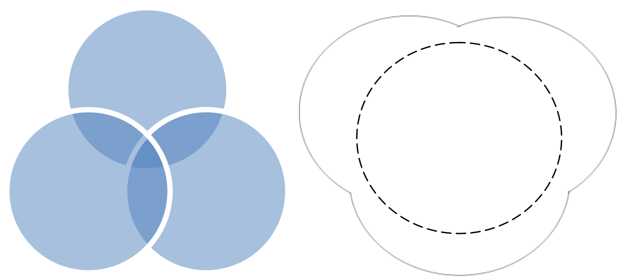

Figure 10: Traditional Venn Diagram vs. Modified Venn Diagram

Within Figure 8, each of the six characteristics' descriptors is represented by a different color (see legend). The purpose of representing the descriptors with different colors is two-fold. First, it visually provides the reader a reference to the different characteristics associated with each of the descriptors. Second, the colors show how the characteristics are related to the Communities of Practice framework through the use of the Venn diagram. For example, one can see that there is a large grouping of red descriptors toward the right side of the figure. The red indicates that these are descriptors for the *Academic Support* characteristic and that they are closely associated with Practice. This connection as well as similar connections are described further later in the chapter.

Not all of the descriptors for the six characteristics identified in this study are present in Figure 9. Some of the descriptors are missing because the Communities of Practice is referring to the University Mathematics Department (UMD), and some of the more personal (in relation to the graduate students) descriptors such as family obligation or responsibilities of graduate students are not directly related to the UMD. Other descriptors appear on the "edge" of the diagram. These descriptors are minimally connected to the Community of Practice of the UMD. An example is geographic location. Geographic location of the UMD is beyond the control of the UMD, but it contributes to the identity of the group as a whole and therefore is considered a minimal part of the Community of Practice. The descriptors not included in the Communities of Practice framework for the collective UMDs include: limited options in graduate schools, size of departments, family obligations and or responsibilities, and satisfaction with choice of program.

From the diagram and the placement of the descriptors for the six characteristics, one can see that the Community region contains a large proportion of the descriptors. On the other hand, fewer descriptors lie distinctly within the regions of Domain and Practice. Some other observations include: a) many of the descriptors associated with *Academic Support* are part of the Practice of the UMDs, b) many of the *Environment*, *Interactions*, *Student Relationship,* and *Faculty Relationship* descriptors are highlighted by the Community element, and c) descriptors for *Attractants* are usually related to the Domain and Community of a Community of Practice.

The next few sections describe what Domain, Community and Practice look like in these six UMD's who graduate a high percentage of women mathematicians at the doctoral level. Each of the three components is addressed separately although overlap is considered in each. The regions are described by the characteristics of the UMDs and their descriptors that have been identified in earlier chapters

What does Domain look like?

Domain is often referred to as the common ground. A common ground helps the members form identities both as individuals and in a group within the Community of Practice as it consists of experiences and quandaries that are shared by members of the department (Wenger et al., 2002). Members of graduate mathematics communities share two common motivations for being there, (1) an interest in the subject and (2) personal satisfaction in working in mathematics (Geraniou, 2010). These experiences and dilemmas have the potential to distinguish between faculty and graduate students' participation in the Community of Practice in some key ways. Therefore, it is necessary to discuss the two groups with a slightly different focus when addressing issues of domain, and later, community and practice.

There are several characteristics from this study that can be associated with domain. The most prominent of these is *Attractants* (see Figure 9). Members of the UMDs are drawn together in their respective departments through an interest in mathematics. This is true for both graduate students and faculty members. Faculty and graduate students choose to become members of a specific UMD. Factors that help faculty and students decide which UMDs to participate in are similar. Both groups have a desire to learn mathematics beyond the undergraduate level and both groups have a desire to share that knowledge with others, either through research or through teaching.

For faculty members this means sharing their knowledge with graduate students, encouraging students to conduct research that produces mathematical knowledge. The faculty share their knowledge with students through a variety of activities, including but not limited to, mentoring and professional development opportunities. These will be discussed in further detail in the community element.

For graduate students, their enjoyment of mathematics has created an opportunity to gather in their respective UMDs to learn graduate mathematics, work on research teams, teach undergraduate classes, and collaborate in course work. Graduate students have each of these activities in common, and this helps to create a sense of common identity.

Geographic location, although it does not appear entirely within the Communities of Practice Diagram (Figure 9), also may contribute to the group's identity outside of mathematics. Many students were drawn to their perspective UMDs because of their geographic locations and different things in which those locations may provide, such as climate. Graduate students reported participating in recreational activities together, and liking the places that they live. These activities also help to create a sense of belonging and common identity of the group.

Finally, the data revealed that UMD members are attracted to these six UMDs for a variety of other similar personal and universal reasons. This may be a result of the possibility that similar types of people search out the departments in this study therefore making it easier for them to share a domain.

In addition to *Attractants* being important in the Domain, *Interactions* also play a significant role. These UMDs facilitate opportunities for interaction among its members.

These interactions help members of the department build relationships. These interactions may help inspire members to participate in different aspects of the community and contribute relevant information such as research (Wenger et al., 2002). The interactions may also create opportunities for members to discuss the development of the key problems and questions within the field (Wenger et al, 2002). These discussions could then lead to "generation," in which scholarly research is demonstrated and helps to hold the community together (Golde & Walker, 2006).

What does Practice look like?

Practice is described as the knowledge that members of a Community of Practice share (Wenger et al., 2002). This knowledge is both formal and informal in nature. Formal knowledge can include content, language, tools, frameworks, teaching and research practices. Formal knowledge is also that which is accepted by the mathematics community as a whole. While informal knowledge may be relevant to only a department or a smaller community within the mathematics community. Informal knowledge may include knowledge that is passed from more experienced graduate students to new students, such as how to find an advisor, who to ask about technology support, or which classes to take and what order to take them in.

Practice is also connected to a larger field than that of the UMD. The mathematics community as a whole historically has dictated some of the formal knowledge. For example, doctoral students in most UMDs have to pass at least three qualifying exams to be considered PhD candidates in the field. However, the content of those exams and the exam procedures are determine by the individual UMDs. The content and procedures for qualifying exams are considered to have elements of both Practice and Community, because the knowledge is shared by the graduate students, and the procedures are determined by the UMD and are a result of some of the beliefs within the community in terms of what is best for the student in preparing them for their future careers.

Many of the descriptors which fall within the Practice region of the Communities of Practice diagram are connected to the characteristic of Academic Support: These UMDs provide different structures for supporting their graduate students throughout their academic careers. This collection of descriptors may be a result of the fact that the department designs these structures for the purpose of creating similar experiences for graduate students, as well as providing a knowledge basis for all graduate students. For example all first year TAs at Preston, Weston and Chelsea attended an orientation prior to the beginning of the semester. These students are provided with information and materials pertinent to their respective universities and departments (DGP interviews).

It is interesting to note that both of the descriptors describing mentoring are a part of Practice. Not all knowledge that is passed on to members is formal and the informal mentoring that occurs between the graduate students provides valuable information and knowledge about the department for new and prospective students. Students in the study reported talking with more experienced students, gathering information about course topics, course instructors, and requirements prior to enrolling in courses each semester. Also, the graduate students provide information related to their teaching assignments with each other. For new students, this information includes where to make copies, get room keys, and setting up on-line software for collecting homework or administering tests.

Mentoring of faculty by other faculty appears to be more formal in nature. However, the mentoring still helps orient new faculty members in the department as well as in the culture of academic life. New faculty at Preston University reported that they had research mentors within the department. These mentors can help new faculty with writing and preparing grants, as well as proof reading and providing feedback on manuscripts for publication.

What does Community look like?

Community describes the social structure of learning and building of relationships within the department. For this element many of the descriptors describing the opportunities for graduate students and faculty members to interact with other graduate students and faculty members appear here. The department encourages these interactions as well as members forming meaningful relationships. Most of the descriptors have some factors that are connected to the Community aspect of the framework.

The Environment descriptors associated with: the UMDs provide a welcoming and diverse environment for graduate student success, are concentrated in the Community aspect of the modified Venn diagram. First, the UMDs make their students feel welcome by providing an environment in which most students do not feel pressure to compete with each other for funding, teaching positions, or grades. The UMDs accomplish feelings of companionship through encouragement of collaboration among the students. The UMDs also provide opportunities for graduate students to interact with faculty in professional settings, such as seminars, colloquia, and conferences. At Preston University, these interactions led some students to believe that they were treated more like junior faculty rather than “slaves” (Graduate Student Interviews).

Part of creating an environment that welcomes all students is associated with creating a diverse climate. A diverse climate may not produce the same feelings of isolation and gender inequity described as a ‘chilly climate’ because the underrepresented groups may have reached a critical mass (Hall & Sandler, 1982; Monroe et al., 2008). Students at the six UMDs discussed both perceptions of gender issues, and the gender diversity among faculty and graduate students. Students at all six UMDs reported that the graduate student body seemed diverse in terms of gender, but the number of female tenure track faculty across UMDs varied greatly. The perceptions of gender issues within the UMDs reflected students’ own experiences or knowledge of the experiences of their fellow graduate students. Students reported that they had not experienced any gender- biased behavior from faculty or other graduate students. They also reported that they were not aware of such behavior. Comments about climate which involved critiquing members’ behavior were small in number and not specifically related to gender. For example, “it’s [Caldwell University] mostly a very nurturing place. We do, of course, have a handful of big shots who are pretty condescending, but they don’t necessarily set the tone for the whole department” (Caldwell University Graduate Student). This particular student did not feel that those “big shots’” behavior was representative of the department, nor did the student feel that it was important to mention their gender.

Even though the students did not feel that gender issues were present in their representative departments, some felt that it still persisted in the field at other universities. .

For example, “An older grad student who has been to more conferences than I says that this university is the best in terms of friendliness *[toward women]* and sincerity in wanting to help you understand math” (Caldwell University Graduate Student). A student from Chelsea explained that “[A]t this point in time I think the department is reasonably comfortable for women. (It's certainly better than my sister's CS department at another university.) I generally feel more uncomfortable (in terms of gender issues, etc) at conferences” (*Chelsea University* GSOQ response). These two perceptions show that some students are still aware of differential treatment of women in the field, but that perhaps it is not as prevalent as it once was.

In addition to the opportunities that faculty provide, the graduate students take advantage of these opportunities and create their own opportunities for building relationships. Therefore the *Student Relationships* characteristic was closely associated with the community element. Two of the most prominent relationship building opportunities that graduate students create are the informal mentoring of newer graduate students and maintaining social connections through activities outside of the department. The informal mentoring of new graduate students typically begins during the recruitment weekend. This is the first contact that graduate students in a department have with prospective students and possibly incoming student for the following year. This initial contact can be a vessel for introducing new members into the community of a department. The faculty also play a role in this initial introduction to the community by scheduling activities for prospective students to partake, such as seminars, classes, and meetings with faculty members and current graduate students.

Students are not alone in their ability to build relationships with other members of their departments and consequently the Community of Practice. *Faculty Relationships* are also a part of the community element. Through the mentoring of new faculty, more experienced faculty in the department pass along both formal (for example, advising requirements, tenure requirements, and course syllabi) and informal knowledge (including advice on now to obtain resources or where to go for advice). Faculty relationships can be related to where the faculty offices are located. Those faculty at Preston University whose offices where not central to the department experienced feeling of isolation and felt that they did not have as much interaction with other faculty members as they would have liked.

Summary

This chapter outlined how the characteristics' descriptors were related to the three main elements of the Community of Practice. It was difficult to try to separate the three elements, as they are intimately linked. Based on the definition and descriptors' relationships to the Community of Practice, it is plausible to conclude that these six UMDs operate as Communities of Practice. That does not mean that they all share identical descriptors. Nor does it imply that every UMD that is a Community of Practice has to have the same exact characteristics and descriptors. A different *selection* of UMDs *that graduate a large percentage of women* could produce different characteristics and descriptors and also be a Community of Practice. *Also, UMDs who do not necessarily graduate high percentages of women could also manifest a different list of characteristics and descriptors as well.* For this study, the evidence through the data analysis shows that the six UMDs all have elements of the each of the three descriptors; Domain, Practice, and Community.   In the final chapter, I will discuss the implications this finding could have on future research and UMDs.

CHAPTER 7: DISCUSSION

Introduction and Evolution of the Study

The purpose of this study was to characterize University Mathematics Departments (UMDs) which had a relatively high percentage of women doctorates. Characterizing university departments is a complex process. The results of this study provide a snapshot of a dynamic and complex system associated with graduate mathematics. Departmental communities are dynamic and evolving because graduate student populations change through commencements and admissions of new students each semester. Faculty and administration and leadership change often as well, particularly in large universities. There are also possible changes to physical surroundings (new building, construction, etc) that may impact the department in new and unforeseen ways. Therefore, this study characterizes the participating UMDs at a specific point in time (2009).

Originally, the study was planned as a gender study that would complement the literature about the reasons women may not be successful in Science, Technology, Engineering, and Mathematics (STEM) fields. To do this, the study took a positive spin on women in graduate mathematics by examining those programs which have many male and female students who successfully complete their degrees. Since the researcher was interested in examining these departments as complex systems, it was necessary to use a theoretical lens that incorporated social aspects of the department as a community. Thus, the work of Communities of Practice (Wenger et al, 2002) was chosen as the theoretical framework for the study. As a result of wanting to highlight positive things departments can do to support women students, and a desire to take a holistic view, the study evolved to focus on *all* students' success and community building in UMDs. The evolution of the study is more encompassing of community issues for all students and has moved my own thinking forward in terms of equal access of mathematics for all students and support of all students within their chosen graduate programs.

In this chapter I will summarize the findings from the three research questions, and discuss the limitations and implications of the study. The chapter will conclude with a section describing recommendations for future research.

Summary of Research Questions and Findings

Research Question 1

Findings for the first research question were discussed in Chapter 4.

R1: What are the characteristics of graduate mathematics departments that have a relatively high percentage of women doctorates in mathematics?

Even though the six UMDs varied in their size, location, and gender composition of faculty and graduate students, they all had a common element; each UMD produced a relatively high percentage of women mathematics doctorates. Therefore a collective case study (Stake, 2005) was used to study these UMDs. An online questionnaire was designed to explore the graduate students' perceptions of their departments and what factors contributed to their success. In addition, website evaluations and interviews with the Graduate Program Directors were conducted. These allowed the researcher to examine the UMDs from a variety of perspectives to triangulate data and search for confirming or disconfirming evidence: public face of the departments, the administrative perspective and the graduate student perspective.

Several characteristics (listed below) were developed and refined from a larger list of themes initially derived from the Graduate Student Online Questionnaire. Descriptors for each characteristic were then used to highlight elements of the UMDs that contributed to students' success and desire to remain in their respective programs.

- *Graduate students are attracted to these UMDs for a variety of personal and universal reasons.* [Attractants]
- *These UMDs provide a welcoming and diverse environment for graduate student success.*[Environment]
- *These UMDs provide different structures for supporting their graduate students throughout their academic careers.* [Academic Support]
- *These UMDs facilitate opportunities for interaction among its members.* [Interactions]
- G*raduate students create opportunities for interaction and value the relationships formed from such interactions.* [Relationships]

These resulting characteristics and their descriptors were not necessarily present at all six universities, but evidence for each was found in at least two UMDs. However, only three descriptors out of 32 (see Table 24) were explicitly evident in two UMDs, while all others were evident in the data from three or more UMDs. This is significant in terms of the types of UMDs. No three UMDs were similar in size, location, or gender composition of faculty and graduate students. This implies that the characteristics and their descriptors have the potential of being present in a wide variety of UMDs. The characteristics in this study are not only connected to the data but also the literature.

The six departments in this study foster interaction between their members and this may encourage faculty and graduate students to be collaborative rather than competitive. These collaborative environments encourage students' mathematical growth through communication and positive relationships (Fox & Soller, 2001; Herzig, 2004b; Tinto, 1993).

Previous research has also shown that competitive environments may influence women to leave mathematics and other STEM disciplines (Blickenstaff, 2005; Ferber, 2003). In contrast, the six departments in this study value relationships and the collaborative nature of the graduate students. The departments demonstrated this through the use of office spaces for the graduate students. Offices that have room for many first year students to be housed together forces them spend more time together on campus. The students can then form lasting friendships. Another way that departments demonstrate that they value relationships and interactions is through providing common areas in the department in which members can meet and discuss mathematics or other topics. Others (Eisenhart & Holland, 2001; Stage & Maple, 1996) have noted that friendships formed by students also contribute to their happiness on campus. The students described the friendships they had formed both in the mathematics departments and outside of the department as being supportive and contributing to their success within the program. This confirms previous studies in which women reported that friendships and meaningful relationships were an important factor in their success in graduate STEM programs (Lips, 2007).

Over-all climate of a department is created through interactions among members. In the past, women have reported various sexist behaviors which they have suffered in the STEM community (Herzig, 2002, 2004a; Rodd & Bartholomew, 2006). In contrast to these past studies, the students (both men and women) here reported that such incidents were extremely rare in their departments and usually limited to individuals. They further described that such behaviors were not condoned by members of the department and were quickly handled. This does not mean that sexist behaviors and attitudes do not exist within these six departments, but that the students participating did not feel they influenced the overall climate.

Research Question 2

The second research question looked more in-depth at one of the UMDs. The findings for R2 are discussed in Chapter 5.

> *R.2 How do the characterizations of the graduate mathematics departments influence the graduate students and faculty members' experiences of the* community within one *particular large mathematics department?*

The case study of Preston University yielded new and enhanced descriptors and characteristics. Preston was chosen because it had the most responses to the Graduate Student On-line Questionnaire, and it contributed to evidence for more of the descriptors than other UMDs. Three additional data sources were collected for this case study: faculty interviews, graduate student interviews, and a new student questionnaire. An additional characteristic was created based on the faculty interviews and supported by the graduate student interviews. This characteristic states that Preston University faculty members create opportunities for interaction among themselves and value the relationships formed from such interactions. This was an important contribution to the findings from the collective case study of all six UMDs, because the in-depth case study was the only time that faculty perspectives were taken into account. It is plausible that this characteristic is present at the other UMDs as well. Two of the other prior characteristics were modified to be more inclusive of faculty perspectives.

- *Members of the departments are attracted to these UMDs for a variety of personal and universal reasons. [Attractants]*

- *These UMDs provide a welcoming and diverse environment for graduate student and faculty success.[Environment]*

Several new descriptors were created using both the faculty and graduate student interviews. These descriptors highlighted events and factors that the faculty and graduate students felt were important to graduate success and happiness. These new descriptors and characteristics may be unique to Preston University. However, it is also possible that they are relevant to the other five UMDs as well.

One thing that stood out in relation to Preston University was the similarity between how the students perceived the roles of their advisors and the faculty views on what an advisor should be. The students valued the relationships they formed with their advisors, while at the same time the faculty enjoyed advising students. Many of the students had philosophies about finding an advisor and were willing (and sometime eager) to pass these theories on to newer students. One such philosophy was the idea that you choose a person for your advisor rather than a field of study, then the advisor. This finding supports the conclusions drawn in previous research that students value relationships and supportive advisors, and considers them to be a factor in decisions to remain in a specific field (Fox & Soller, 2001; Herzig, 2004b; Tinto, 1993).

A second factor was the support that both students and faculty felt they gave and received. Graduate students supported each other through informal mentoring. The more advanced students (in terms of years spent in program) would offer advice and support to the newer students. This support was in the form of helping new students choose classes (and professors), helping the new students with class material through study groups and notes from prior classes, and supporting each other in preparing for qualifying exams. For both the students and the faculty, the acts of support are a way for new members to learn about the culture, value, and attitudes of the people within the community (Austin, 2002). The support techniques also help new members of the department to learn the practices, and the socialization associated with the community aspects of the Communities of Practice framework.

Learning the social structures of the department is important for students to acquire because they may help scaffold Zeldin et al.'s four sources of self-efficacy (2007). The new students and faculty gain *authentic mastery experiences* in which they are successful, which subsequently boosts their self-efficacy beliefs about their mathematical ability. The support structures also provide a foundation for students to gain *vicarious experiences,* or watching others. The students and faculty gain these experiences through seminar's and colloquia. However, the environment within these activities is not competitive, but rather friendly and engaging.

Research Question 3

Finally, the third research question explored how the characteristics and their descriptors from the first two research questions were connected to the theoretical framework of the study: Communities of Practice (Wenger 1998; Wenger et al., 2002).

R.3 *How are the three aspects of the Communities of Practice framework related to the characteristics of the graduate mathematics departments?*

By organizing the descriptors in such a manner as to relate them to the three elements, Domain, Practice, and Community, the researcher was able to explore which descriptors might illustrate each of the elements. Many of the descriptors were related to more than one of the elements while other descriptors and their characteristics were related to a single aspect of the Communities of Practice framework (see Table 27 and 28 and Figure 9). The descriptors associated with *Interactions* were not concentrated in any one area of the figure. These descriptors could be linked to community through the relationships which were formed during the interactions. The connection to domain was correlated to the fact that relationships and experiences help form the mathematics identity of the community members. And descriptors associated with interactions were a part of the practice, because the UMDs share formal knowledge through specifically oriented types of interactions such as seminars.

Other characteristics were more closely related to a single aspect of the Communities of Practice. For example many of the *Academic Support* descriptors were connected to the Practice element, while *Environment* descriptors were more closely connected to Community. It is important to note that only one of the descriptors stood alone within a single element. This descriptor was *geographic location.* The location in which one chooses to live can have an impact on the identity of the group. Therefore it remained in the framework but was left also as a possibility that its influence on the Community of Practice within the department may be minimal.

However some descriptors rather than characteristics were more closely related to all three aspects than others. For example, *informal mentoring* and *faculty mentoring* were placed in the center of Figure 9, because the informal mentoring of both graduate students and new faculty members by their peers can be describe by all three parts of the

Communities of Practice. It is Practice, because the members of the UMD carry on the role of mentors by choice; Community because the members form relationships and build trust among the group through the act of mentoring; Domain because the mentoring of newer members is part of the group's identity.

In addition to having elements of a Community of Practice as an entire department, University Mathematics Departments (UMDs) may have many smaller Communities of Practice. Within these smaller communities different members of the department may participate. The purpose of this study was not to describe all of the different types of Communities of Practice and their membership. Rather the aim is to address the UMDs' Community of Practice as a whole and what it might look like.

The UMDs in this study are Communities of Practice. They all have descriptors that support each of the three elements of the Community of Practice (see Appendix R). In other words each of the six UMDs is providing the opportunities for their students to be integrated into the department communities and cultures. During this process the students are able to make the transitions through the phases of the PhD.

Part of the successful transitions is the collaborations between the students. The collaborations encourage student's mathematical growth through their interactions (Fox & Soller, 2001; Friedman, 1995). In addition to increasing student's content knowledge collaboration is also an effective way for members of the department to become participants in the Community of Practice (Wenger et al., 2002). The community and interaction between the members also contributes to the major roles outlined by the Carnegie Initiative as the "steward of the discipline" (Golde & Walker, 2006). Students learn content specific to their field through attending class, and course work, but also through their interactions and discussions during study groups. The nature of mathematics courses work and homework problems may contribute significantly to the students' interactions and discussions during such study groups. The problems can be attempted individually and then discussed. Students discover different ways of thinking about the problems and mathematical topics through such interactions. In addition, these study groups are opportunities for students to build relationships with their peers, reducing feeling of isolation that can cause some students to leave their programs (Geraniou, 2010). A second contribution the study groups make is to teach students how to pass their knowledge on to others, the second role in the "stewards of the discipline" (Golde & Walker, 2006).

During collaborations, students may take part in informal mentoring as well, especially if the study group is composed of students from more than one cohort. This mentoring is a passing on of knowledge that may not be written in any handbooks. Such knowledge is valuable in its power to help students succeed in their programs. Mentors can be role models. Older students have the capability of inspiring and guiding younger students through their academic aspirations (Lips, 2007). Therefore the informal mentoring becomes a venue for new and prospective students to see what can be achieved within the given department.

Students are not the only members of the UMDs. Faculty also play a large role in establishing the Community of Practice. Faculty advisors and mentors can also be role models for their students. They actively demonstrate daily responsibilities of faculty life and what it means to be a mathematics researcher. Women mathematics students need role models of both genders that are successful in their careers. However, role models do not have to be “untouchables”, they need to be knowledgeable and skilled in their areas of study (Marx & Roman, 2002).

Being skilled and knowledgeable in your field is essential to being able to pass on the *practice* of mathematics. The practice of mathematics is passed on through the training of apprentices in the graduate programs (Herzig et al., 2006). However, you cannot apprentice if there are no interactions between members of the department and if relationships are not formed. Therefore, the UMDs in this study provide many different ways students and faculty can interact with each other and form relationships beyond the student/advisor roles.

Domain has been the least addressed element of the Communities of Practice in this study. Perhaps, domain is the most difficult to measure, due to its association with identity. However, it should be noted that the domain of the UMDs in this study is not considered independently from the other two elements. Identities are often formed through our interactions. The domain is what inspires members to participate (Wenger et al., 2002). These inspirations can be from internal motivations such as interest in the field or external motivations through discussions with other members and applications of knowledge (Geraniou, 2010).

Limitations of the Study

Reflecting on the study after its completion led to several critiques that can limit the applicability of the results. These critiques are connected to sample limitations, participant limitations and research design limitations.

Sample Limitations

The participating UMDs were created using a combination of purposeful and convenience sampling. Originally, 25 UMDs were invited to participate because they each had a record of producing women doctorates in mathematics (based on a Jackson, 2004; Herzig et al., 2006; and a website database for college selection). The prospective participants varied greatly in size of university and geographic location, as well being both private and public university. The original study design planned for about 15 participants for the first three Phases of the study, and three participants for the in-depth case study. However, only six UMDs were willing to participate in the study. Therefore, the original sample size was greatly reduced and thus correspondingly reduced the ability to generalize the characterizations beyond the study's participants.

Despite the small number of UMDs participating in the study, some connections can be made among these six UMDs and other UMDs that may have similar members and characteristics. UMDs that have similar members in terms of gender may share characteristics with the UMDs in this study. For example, they may build learning environments that are not competitive, encourage faculty members to become mentors rather than advisors, and have a variety of support structures in place for supporting the success of their graduate students.

Participant Limitations

The request to complete the Graduate Student Online Questionnaire (GSOQ) was submitted to all students in the six UMDs. Students were not tracked, nor did they receive compensation for their responses. Therefore, the participants were also a convenience sample of those willing to commit the time to fill out the survey (Marshall, 1996). The survey was also limited in the amount of demographic data collected from students. Due to the fact that specific demographic information was not considered initially, it has made the responses to the research questions limited. For example, nationality and ethnicity were not considered in this study. I have no way of knowing the demographics associated with these factors and it therefore limits the generalizations about the graduate student populations.

In the in-depth case study, the graduate student interview participants were selected based on two criteria: they had to be enrolled in a PhD mathematics program within their UMD and have at least one hour available to participate in a semi-structured interview. Therefore this was a criterion sample (Gall, Borg & Gall, 1996). The graduate student interviews do not provide population validity for the larger group, because it is not representative of the entire Preston UMD population (Gall, Borg & Gall, 1996). The volunteers were not a diverse group of students in terms of nationality and ethnicity.

The faculty interviews were much more balanced in terms of the number of men (7) and women (5) participating. There was also a greater diversity among the faculty in terms of nationality of participants. However, the participants were volunteers and therefore there was not as much diversity as could have been possible.

Research Design Considerations

In an attempt to gain a holistic picture of the UMDs participating in the study, the study was designed to encompass a variety of different perspectives through the eyes of the graduate students, faculty members, administration, and public face of the UMD through their Websites. However, upon reflection of the data collected in both the Graduate Student

On-line Questionnaire and the case study interviews, two important members were not represented: departmental support staff and post doctoral research associates.

It became clear that the graduate administrative staff played a role in acclimatizing students to their new departments. They were seen as sources of knowledge both concerning graduate school procedures and regulations (Preston University Case Study) and basic office issues such as making copies, finding paper, and locating building keys (GSOQ). The graduate staff work with both students and faculty and would have provided a valuable link to the connections between to the two populations.

The second group of people in the UMDs that was not included in the study was the Post-Doctorates. This factor appeared prominently in the case study through the graduate student interviews. This group of people seemed to be an important resource for the graduate students. They describe working with the Post-Doctoral members on their research teams, going to them for advice, and asking for help on mathematics problems. The graduate students who are in regular contact with Post-Doctorates seem to view them as mentors in addition to their faculty mentors.

Implications

Implications of this research include helping researchers and educators understand why specific educational environments are appealing to large numbers of women choosing to study mathematics and who are also successful in earning mathematics doctorates. From this study, a variety of tools and characteristics have been discussed that may be able to help UMDs and other STEM fields diversify their departments.

One of the original goals of this research was to address issues that surround women's underrepresentation in graduate mathematics programs and look for solutions to increasing the number of women who participate. Through examining six UMDs that do have high percentages of women doctorates in mathematics the following recommendations can be made for possibly increasing women students in other UMDs.

1. Departments can provide opportunities for women graduate and undergraduate students involved in research early in their mathematics careers.

Women (and men) have limited images of what mathematicians do (Picker & Berry, 2000). Students from Preston University stated that they did not know what mathematics research entailed nor the variety of paths and opportunities mathematicians had until they were involved in research. These research opportunities can range from formal REUs and REGs to smaller projects with a department. The research projects excite the students about the range of future possibilities and expose them to different working environments (outside of course work) within the mathematics community. These projects can also help students start building relationships and fostering interactions. In large mathematics departments, there may be many different types of research taking place at any one time. Students may have the opportunities in these departments to be a part of those projects in small ways that give them a task for the research. The availability of research projects is not a guarantee in all UMDs or in all graduate STEM departments. However, the department can make students aware of opportunities that are available outside the department of which students may want to take advantage. Examples of opportunities include the Nebraska Conference for Undergraduate Women in Mathematics (http://www.math.unl.edu/~ncuwm/12thAnnual/) and the American Mathematical Society travel grants for faculty and students attending conferences, as well as programs and resources for graduate, undergraduate, and high school students interested in mathematics.

2. The department should provide a variety of opportunities for women to interact with each other and with other members of the department.

The departments in this study provided a variety of ways that students and faculty could interact in non-threatening situations, the most common being seminars. Graduate students in the study reported enjoying their seminars and have the opportunities to interact with their peers and other faculty members in their fields of interest in a safe environment. In these types of environments the students were able to continue learning and make mistakes without fear of criticism from other members of the community (Wenger et al., 2002). These types of interactions build the community in which members work together rather than against each other. In addition to the more formal seminars, students and faculty can participate in less formal gathering such as departmental teas and social events. These events allow students and faculty to interaction in a different type of setting and yet still foster relationships.

Other examples of opportunities for interaction include involving students in recruitment of prospective students. Word of mouth and recommendations from current students were factors in many of the graduate students' choices in selecting their graduate programs.

3. Departments should equally provide funding for women and men.

In the past, women were not as likely to receive the same levels of funding as men and often had to support themselves through graduate school (Vetter, 1996). Funding in specific departments was published in the AMS/MAA Assistantships and Graduate Fellowships handbook. This handbook provides information on programs about their funding types, stipend amounts, and number of assistantships available each year (2009). Funding has been shown to be a factor in attrition from programs (Herzig, 2004a) and in choosing a program (Chapter 4). For the six mathematics departments participating in this study, no such difference in funding was found between men and women. Funding for the majority or all of the graduate students in mathematics departments may be more common than in other STEM departments. Mathematics departments often serve most of the student body in terms of the number of students enrolled in undergraduate courses. Mathematics departments are considered to be service departments for the institutions in which they serve. Therefore, there may be many sections of lower level courses for graduate students to be teaching assistants for. By having a consistent need for first and second year mathematics courses, such service departments can guarantee a large number of teaching assistantships. Departments such as engineering that do not provide courses for students outside the department may not have as many guaranteed graduate student assistantships and have to find other ways of funding their students. These alternative funding sources (e.g., grants) may not be a plentiful and can be unpredictable.

4. Departments need to foster warm and welcoming environments.

An environment that is warm and welcoming does not purvey a “chilly climate” in which women experience (or perceive) differences in their treatment versus their male peers (Hall & Sandler, 1982). Men and women graduate students did not feel that chilly climates were established or the norms in their departments. The graduate students reported in the GSOQ that men and women were treated fairly as a whole.

The men and women in this study talked about gender in two meaningful ways. First in terms of number of women in the department, and second, in terms of how men and women are treated in the department. By discussing the number of women in the department the students addressed the idea central to critical mass (Monroe et al., 2008). Women students did not feel like they were isolated from same gender peers, and that they were rarely the only women in their classes. Thus, departments would be well served to take initiatives to have a critical mass of students in each gender.

5. Recruitment of women (and other students) should involve a personal touch

Students who responded to the GSOQ and participated in the graduate student interview often mentioned recruitment weekends as being factors in their decisions to attend (or not) specific universities. These weekends help prospective students to gain a more realistic outlook of the department. They had the opportunity to interact with faculty, staff, and current students. They attended classes and seminars. Student involvement in recruiting weekends and luncheons may give a more "human" face to the department, making students feel like they would fit in with this group of people. One aspect of the recruitment and acceptance procedure mentioned specifically during the case study was the involvement of the Graduate Program Directors. Students stated that the DGP answered questions, helped with first semester registration and other campus formalities prior to the students arriving on campus.

6. Departments should design websites that show how the faculty value students and support diversity.

As the public face of the department, the departmental website can send a message to prospective students and faculty. Through designing the website evaluation tool (Appendix J), the researcher discovered how intricate these details can be. This rubric can be used to self assess the departmental website and determine areas in which the website could use improvement. For example, a university that posts pictures of faculty instructing students and students in a passive role instead of students working with each other or with faculty members may convey messages that collaboration is not valued or unimportant to the culture of the department.

7. Departments need to foster opportunities for graduate students and faculty members to form meaningful and trusting relationships.

Much of this study and its results focused on the community elements of the UMDs which participated. Through Graduate Student Online Questionnaire, graduate students discussed important factors that contributed to their success at their respective universities. One of the initial content themes from the coding of the responses that really stood out was the number of times the graduate students mentioned the importance of certain people in the department and their relationships with those particular people. None of the participants in this study reported unhealthy relationships with faculty mentors as had been mentioned in previous literature (Etzkowitz et al, 1994). Therefore, it is important for departments to foster relationships, both social and professional, between its members. These meaningful relationships are important in the success of students (particularly women) (Herzig, 2004). Relationships can be fostered through a variety of activities. These activities can include regular department teas where members meet once a week to socialize with people that they do not normally work with or to meet new people. Another type of activity that builds relationships is graduate student seminars. These types of seminars are associated with less anxiety and stress by the graduate students, because faculty are in attendance by invitation only. The seminars can be designed to help the students prepare for conferences and other types of presentations.

Another type of relationship that participants discussed was the relationships between students and advisors. Many students felt that their faculty advisors played important roles in their success as students. They were often described as mentors in the Preston University graduate student interviews. The faculty provided a variety of support for the students in terms of helping the students learn to conduct mathematical research, work in teams, and prepare for future careers. Students with faculty mentors at Preston University stated that they were involved in mathematical research early in their graduate school careers. This involvement helped them to understand what research entailed, and to get them excited about doing it. Not having faculty advisors and meaningful relationships between the faculty advisor and the graduate students has been linked to a factor students cite when choosing to leave their graduate fields (Austin, 2002; Etzkowitz et al, 1994; Fox, 2003).

In this study, the relationships were important to the graduate students, and helped to keep them enthusiastic about the mathematics as well as support their learning. This finding contradicts earlier findings by Duffin & Simpson in which they suggest that students should rely less on others to help them in learning mathematics and become more like mathematicians (2002). According to Burton, mathematicians are shifting how they research and moving to collaboration and working with others (1999). The students in this study do rely on each other in a collaborative nature where they work together in order to be successful in their departments.

According to Geraniou, there are two transitions for graduate students where graduate students would need different types of relationships to support them (2010). Early in the process (usually during the first two years) some students struggling with coursework questioned whether or not the program was for them. This was true for the students in this study as well. Many students struggled through the transition from undergraduate to graduate programs. At this juncture many students in this study reported that they relied on each other (by forming study groups and exchanging notes) and faculty members (through interactions during office hours) to help them successfully complete their courses and subsequent qualifying exams.

Later during the dissertation writing phase of the program, some students built meaningful relationships with their advisors in which they valued the guidance and support that the advisor provided. The advisors effectively became mentors to the students teaching them how to conduct mathematical research and providing feedback as well as helping the students set time limits for their work (Geraniou, 2010).

Broader Impact

The implications and previously discussed recommendations of this study may or may not be limited to graduate mathematics programs. One of the strengths of the study is highlighted by using the Communities of Practice Framework (Wenger, 1998; Wenger et al., 2002). The six characteristics of the UMDs are written such that it appears that the context of a mathematics department may not be the most notable factor. However, these characteristics were developed by grouping the descriptors, many from all six UMDS. These descriptors may be specific to mathematics departments and the nature of graduate work in mathematics. For example, the nature of mathematics course work may be a major factor in encouraging students to form study groups, to discuss problem sets and concepts, share course notes, and study for qualifying exams. Another example which may be unique to mathematics departments are the relationships built among graduate students who all share a common office space. Mathematics departments who are able to hire a large number of graduate TAs and have the space for these students share large common offices can foster opportunities for interaction and relationship building within the graduate student population. These types of interactions and funding availability may or may not happen in other graduate fields of study.

However, if we examine the six characteristics developed from both the collective case study and the in-depth case study, one can see that they are not specific to a discipline or level of education. Then, if one only considers the characteristics as broad statements, the findings may be utilized in different settings.

- *Members of the departments are attracted to these UMDs for a variety of personal and universal reasons.* [Attractants]
- *These UMDs provide a welcoming and diverse environment for graduate student and faculty success.* [Environment]
- *These UMDs provide different structures for supporting their graduate students throughout their academic careers.* [Academic Support]
- *These UMDs facilitate opportunities for interaction among its members.* [Interactions]
- G*raduate students create opportunities for interaction and value the relationships formed from such interactions.* [Relationships]

- *Faculty members create opportunities for interaction among themselves and value the relationships formed from such interactions*. [Faculty Relationships]

These characteristics along with most of the descriptors may be used as initial benchmarks for other STEM departments who wish to be successful in graduating large percentages of women from their programs.

Another perspective for extending this research to other STEM fields may include using the characteristics defined in this study as an initial lens for examining the practices, domain, and community. This type of study would yield information on if the characteristics are true for other STEM fields and what additional characteristics would need to be defined. For this reason, I believe this study has a much wider application than simply graduate mathematics. In addition to being adaptable for other STEM departments, these findings can be used to improve enrollment and success in undergraduate mathematics programs as well.

All graduate work is based on a students' desire to continue learning in the field and typically includes a deep passion for the subject. Students at the undergraduate level in STEM may find it hard to form personal connections to the subject areas they have chosen to study (Geraniou, 2010). This means that undergraduate courses and programs in STEM should create opportunities for students to form those connections. One such way to do this is through early research experiences and application of the material that students are learning. Departments can provide these experiences through capstone projects involving research experiences, REU opportunities and information for REUs at other universities, and through an applications class the student's senior year in which they are responsible for completing a small research project.

Students can start to build relationships with that will carry through to graduate school through work on REUs. If they attend summer REUs away from their home universities, they meet current graduate students and faculty at other departments. The students can begin to learn about graduate school opportunities through these relationships as well as begin to investigate what graduate school is like.

STEM advisors play a critical role in helping students aspire and succeed in graduate school. Students in this study highlighted the importance of undergraduate advisors in their choosing to attend graduate school, and in choosing where to apply to graduate school. They formed bonds with their undergraduate advisors and respected their advice.

Community Connections

Community as described by Wenger et al., (2002) was the social fabric of learning. However, community has many meanings including a group of people living in a particular area, or a group of people having common culture, having shared knowledge and values. These different definitions and results from the study lead me to agree with Hancock, when she explains that mathematics should not be viewed as a set of universal truths, but rather as a cultural product (2001). For this study, it means that the learning and teaching of mathematics at the graduate level is a community product, and each community collectively develops its own knowledge and values. The six UMDs described here have built cultures in their departments that support the success of all their students in gender diverse environments. This is not to say that there is only one such type of community. But that collegiate departments and high school departments can strive to build communities in which the learning and teaching of mathematics is a community product, one in which all members contribute in different ways.

Community-building has become important in the professional development of high school teachers. Through recent efforts in creating professional learning communities at the high school level, teachers are learning to study students' mathematical learning and improve instruction (DuFour, 2004; Mason, 2003). The conditions for improving teaching and learning in mathematics are improved when teachers work collectively rather than in isolation (Little, 2002). Through collective work teachers are able to make teaching and learning a community product rather than an individual product. This research highlighted how important it was for students in the UMDs to collaborate in their graduate work and for faculty members to be able to collaborate on their research. Collaboration among mathematics teachers in high school might have a similar positive effect on their feelings of professionalism and their individual successes in their practice.

Further, NCTM states that "mathematics is a part of cultural heritage" (2000, p 4). The culture of mathematics is passed on to future generations through the education and communities at all levels. At the graduate level, mathematics communities pass on the cultural and intellectual achievements of the field. Through the passage of this knowledge and the interactions between members of the graduate department, students develop an appreciation and understanding of those mathematical achievements, and understand the importance of passing on this knowledge and creating new knowledge (Golde & Walker, 2006). The characteristics and their descriptors highlight many of the cultural aspects of the mathematics departments.

The values that were important for graduate students in this study were connected to the Environment and Academic Support they received. The students described departments in which the focus was not on the product but rather on the process. Meaning that the students felt the department members cared about their experiences and provided opportunities and environments in which students would build relationships and succeed rather than a department that only wishes to produce PhDs in mathematics.

Recommendations for Future Research

Research that focuses on communities and their elements in mathematics has a variety of directions it can go. Those directions include building on the current research in a manner that would address some of the limitations mentioned above, conducting studies on climate and departmental climate in departments which are not known for their diversity, and extending the study to K-12 classrooms. Each of these directions is outlined below in further detail.

Research that would further the findings here would include interviewing a wider variety of students in terms of ethnicities and nationality to give a broader view of the nature of a UMD community. I also believe that culture plays a role in the importance of that community and its role in student success. Therefore an additional research question might address how different cultures view the climate of a UMD and its role in supporting students through a Doctoral Program.

Another interesting finding that resulted from the in-depth case study of Preston University was the relationship between transfer students, meaning those students that earned Master's degrees elsewhere and the graduate student community. From the three interviews conducted from Preston's UMD in which the graduate students had already earned masters, the students revealed that they had less contact with the other members of their "cohort" because they were not required to take the same courses. Nor did they feel a strong connection to the "new" students. This would be an interesting lead to follow, because students do transfer universities after completing Master's degrees. Further, the reasons why they move are also relevant. These factors could contribute to the knowledge about what types of UMDs students seek out in terms of climate and community attributes.

Third, the UMDs in this study had a wide range in terms of women tenure track faculty members, which many of the students commented on in the GSOQ, either stating that there were many women or they wished there were more women faculty. Research connected with the theory of critical mass states that by having more women in positions of power (tenure track faculty positions) it has the potential to change the climate of the department (Etzkowitz et al, 2000). If this is true, it would be interesting to examine how having women faculty members change the climate of UMDs.

Future research could include using the six characteristics and their respective descriptors as a lens for investigating other STEM departments that are successful in graduating women doctorates. A compare and contrast analysis of the UMD characteristics and other STEM department characteristics would highlight those elements in which the departments had in common as well as those elements unique to specific fields.

Through my work and discussions with Preston University's Mathematics department and its members, I developed another theory connected to the Communities of Practice which is worthy of exploration. This idea elaborates on the UMD as a Community of Practice to examining the possibility that an UMD may consist of several smaller Communities of Practice. This possibility was highlighted during the in-depth case study of Preston University. Students and faculty working with in specific research areas have close connections to one another. They often collaborate on projects, enroll in similar classes and spend time together in research meetings. It is worthwhile to investigate this type of working environment, and the possibility that it may foster these smaller Communities of Practice especially within larger departments.

The second area for further research is conducting studies on departmental climate in departments which are not known for their diversity. An exploration of these types of UMDs could lead to different or related characteristics as those found in this study. A comparison could be made between the two groups. This comparison would allow researchers to examine possible differences between the two groups of UMDs. The differences and similarities would lead to a greater understanding of the climates in various UMDs, and how those climates impact student learning and the community elements as described by this study.

Research can be conducted using the Communities of Practice framework in other settings as well, including both undergraduate mathematics and K-12 classrooms. In the future, similar research connected to the Communities of Practice can take place at the undergraduate level and at the high school level in which diverse populations are present. Discovering the characteristics that lead these departments or classrooms to be diverse and have large numbers of students become successful in studying mathematics will help students engage in mathematics. While undergraduate research concerning Communities of Practice may be similar to my dissertation research on graduate programs, research on Communities of Practice at the high school level would need to take a different approach, because the high school has different parameters than graduate departments. This research may focus on micro-communities which are facilitated by teachers in the classroom. These community cultures may be instrumental in encouraging more students to study mathematics.

From the research presented here, it appears that the Communities of Practice frame for the K-12 classroom may promote opportunities for all students to learn. Arguments for meaning centered classrooms also encompass the same basic ideas as the Communities of Practice. For example, Jensen promotes the argument that we are social beings and that our brains grow in social environments (1998). This argument supports the basic beliefs behind the community element, in that it is the social foundation for learning. Further in meaning centered classrooms all students have the opportunity to experience *cognitive conflict.* Through collaboration, presenting ideas, questioning the ideas of others, and justifying and defending solutions students are in *cognitive conflict* where internal pressures drive the learning rather than external (Hiebert et al., 1997). Throughout the collaboration process, students are learning to *practice* mathematics through meaningful interactions, and build relationships within the *community*.

Conclusions

This purpose of this study was to examine the characteristics of gender diverse graduate mathematics programs. It was unique in the approach for discovering why students were successful in these programs and which characteristics the graduate students, administration, and faculty members highlighted through their responses in the different data collection methods. The findings in the study are supported by the literature in an unusual way. For example, one of the reasons cited for women leaving mathematics is a lack of mentors and role models (Herzig, 2002; Marx & Roman, 2002). This study found that the students in the six departments were mentored by faculty members and more experienced graduate students and were able to find role models within the departments. Therefore the UMDs filled a void that was shown to be one of the reasons students (and women in particular) left mathematics.

The literature review focuses on why women choose to leave various STEM fields, mathematics in particular, and why students chose to leave graduate education in general. The results from this study provided a rare look at characteristics of these graduate programs that promote the success of their women students, developed by coordinating multiple perspectives and experiences from members of the department. However, the results were not limited to women. Both men and women participating in the study highlighted similar reasons for why they chose their respective departments, why they stayed after completing a master's degree, and why they would recommend that UMD to prospective students. The findings were not limited to a specific gender in terms of who said them, or who was aided and successful in the programs. Therefore, the findings can be used to help departments support the success of all their students regardless of the gender composition. Gender was not a salient factor in this research; rather how a department integrated its members and provided opportunities for them to build meaningful relationships and interact in a variety of ways was the most significant factor.

What has made this study so powerful is that the research has tried to understand the perspectives and experiences of many community members. Highlighting the roles that different members play and their importance as a dynamic quality within the Community of Practice (Wenger, 1998). The study has coordinated multiple lenses and multiple participants for the purpose of gaining a holistic view of a graduate mathematics department's Community of Practice.

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APPENDICES

Appendix A: Consent Forms

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Director of Graduate Programs or Administrative Equivalent (Phase I)

Title of Study: *Recruiting and Supporting Graduate Women in Mathematics Departments*

Principal Investigator: Amanda Lambertus Faculty Sponsor (if applicable): Hollylynne Lee & Karen Keene

You have been chosen to participate in this study because of your reputation for recruiting and graduating high percentages of women doctorates in mathematics. The purpose of this study is to identify aspects of successful graduate mathematics programs in recruiting and graduating women doctorates. Your department's participation in this may help inform other of successful techniques for recruiting and retaining women mathematics doctorates. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. If you do not understand something in this form, it is your right to ask the researchers for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher named above.

PURPOSE OF THE STUDY
The purpose of this study is to examine the practices of mathematics departments with a high percentage of women graduating with doctoral degrees. The researcher hopes to discover what practices and policies encourage women to attended and graduate from these universities.

INFORMATION
The Directors of Graduate Programs or administrative equivalents that agree to participate in this first study will be asked to: (1) grant access to internal documents pertaining to graduate student recruiting and retention, (2) you will participate in a phone interview lasting 30-45 minutes, (3) you will aid in the solicitation of volunteers to complete the graduate student online questionnaire, (4) the you will have the opportunity to add questions to the graduate student online questionnaire, (5) they will receive aggregate data from the graduate student online questionnaire, and (6) state whether or not they would be willing to participate, if chosen, in Phase III of the study.

RISKS
There are no foreseeable risks to the participants.

BENEFITS
University mathematics departments agreeing to participate in this study will be able to add up to three questions to the graduate student online survey in order to help with program evaluation. The results of these surveys will be given to the Director of Graduate Programs or administrative equivalent in aggregate form. Participation may help highlight practices and strategies that are successful in the recruiting and retention of women in graduate mathematics. The results of this research may benefit those departments and institutions wishing to improve the diversity within mathematics and possibly other fields. The ultimate goal is to inform more universities of the successful measures taken by these mathematics departments in recruiting and retaining women doctorates.

CONFIDENTIALITY
The interviews will be audio recorded and kept confidential. All participants will be assigned an alpha-numeric code. The list of codes and participants will be kept in a separate location than the data. The information in the study records will be kept strictly confidential. Data will be stored securely in a locked cabinet and a password protected personal computer. No reference will be made in oral or written reports which could link you or your department to the study. You will not be asked to write your name on any

study materials so that no one can match your identity to the answers that you provide. Documents collected will also be coded references and names of individuals and universities will be removed. These documents will be kept in a look filing cabinet. All data including audio recordings will be destroyed 1 year after the completion of data analysis, or if you withdrawal from the study at any time.

CONTACTS

If you have questions at any time about the study or the procedures, you may contact the researcher, Amanda Lambertus, at ajlamber@ncsu.edu, (919)607-6996. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Arnold Bell, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-4420) or Mr. Joseph Rabiega, North Carolina State University, IRB Coordinator, Box 7514, NCSU Campus (919/515-7515).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

Please check all areas in which you are willing to participate. Note: you do not have to participate in all six aspects to participate in the study.

☐ (1) grant access to internal documents pertaining to graduate student recruiting and retention

☐ (2) participate in a phone interview lasting 30-45 minutes

☐ (3) aid in the solicitation of volunteers to complete the graduate student online questionnaire

☐ (4) would like to add questions to the graduate student online questionnaire

☐ (5) receive aggregate data from the graduate student online questionnaire

☐ (6) be willing to participate, if chosen, in Phase III of the study

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature_______________________________________Date _________________

Investigator's signature__________________________________ Date _________________

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Survey Participants (Phase II)

Title of Study: *Recruiting and Supporting Graduate Women in Mathematics Departments*

Principal Investigator: Amanda Lambertus Faculty Sponsor (if applicable): Hollylynne Lee & Karen Keene

You are being asked to participate in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of this study is to identify aspects of successful graduate mathematics programs in recruiting and graduating women doctorates. If you do not understand something in this form it is your right to ask the researchers for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher named above.

PURPOSE OF THE STUDY

The purpose of this study is to examine the practices of mathematics departments with a high percentage of women graduating with doctoral degrees. The researcher hopes to discover what practices and policies encourage women to attended and graduate from these universities.

INFORMATION

By agreeing to participate in this study, you will be asked to complete an on-line survey. This survey should require between 15 20 minutes of your time depending on the amount of information you choose to provide.

RISKS

There are no foreseeable risks to the participants.

BENEFITS

There are no direct individual benefits for participating in this research. However, their participation may help highlight practices and strategies that are successful in the recruiting and retention of women in graduate mathematics. The results of this research may benefit those departments and institutions wishing to improve the diversity within mathematics and possibly other fields. The ultimate goal is to inform more universities of the successful measures taken by these mathematics departments in recruiting and retaining women doctorates.

CONFIDENTIALITY

The surveys will not require students to submit their names. School information will be immediately assigned a code. This code will be kept separate from the data sources. The information in the study records will be kept strictly confidential. Data will be stored securely in a locked cabinet and a password protected personal computer. No reference will be made in oral or written reports which could link you or your department, or university to the study. You will NOT be asked to write your name on any study materials so that no one can match your identity to the answers that you provide, unless you are willing to participate in further research and wish to be contacted. All data including audio recordings will be destroyed 1 year after the completion of data analysis, or if you withdrawal from the study at any time.

CONTACTS

If you have questions at any time about the study or the procedures, you may contact the researcher, Amanda Lambertus, at ajlamber@ncsu.edu, (919)607-6996. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Arnold Bell, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-4420) or Mr. Joseph Rabiega, North Carolina State University, IRB Coordinator, Box 7514, NCSU Campus (919/515-7515).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature_______________________________________ Date _________________

Investigator's signature___________________________________ Date _________________

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Interview Participants (Phase III)

Title of Study: *Recruiting and Supporting Graduate Women in Mathematics Departments*

Principal Investigator: Amanda Lambertus   Faculty Sponsor (if applicable): Hollylynne Lee & Karen Keene

You are being asked to participate in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of this study is to identify aspects of successful graduate mathematics programs in recruiting and graduating women doctorates. If you do not understand something in this form it is your right to ask the researchers for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher named above.

PURPOSE OF THE STUDY

The purpose of this study is to examine the practices of mathematics departments with a high percentage of women graduating with doctoral degrees. The researcher hopes to discover what practices and policies encourage women to attended and graduate from these universities.

INFORMATION

Participants will complete a short (45-75 minute) interview in which they will be asked about their experiences and perceptions of the mathematics department. The interview will take place on your university campus in a setting in which you feel comfortable. These interviews will be audio recorded.

RISKS

There are no foreseeable risks to the participants.

BENEFITS

Individuals participating in this study will receive $5 gift cards to the campus bookstore or coffee shop upon completion of the interview. Their participation may help highlight practices and strategies that are successful in the recruiting and retention of women in graduate mathematics. The results of this research may benefit those departments and institutions wishing to improve the diversity within mathematics and possibly other fields. The ultimate goal is to inform more universities of the successful measures taken by these mathematics departments in recruiting and retaining women doctorates.

CONFIDENTIALITY

The interviews will be audio recorded and kept confidential. All participants will be assigned a pseudonym that will be kept separate from the data sources. The information in the study records will be kept strictly confidential. Data will be stored securely in a locked cabinet and a password protected personal computer. No reference will be made in oral or written reports which could link you or your department to the study. You will not be asked to write your name on any study materials so that no one can match your identity to the answers that you provide. All data including audio recordings will be destroyed 1 year after the completion of data analysis, or if you withdrawal from the study at any time.

CONTACTS

If you have questions at any time about the study or the procedures, you may contact the researcher, Amanda Lambertus, at ajlamber@ncsu.edu, (919)607-6996. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Arnold Bell, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-4420) or Mr. Joseph Rabiega, North Carolina State University, IRB Coordinator, Box 7514, NCSU Campus (919/515-7515).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature____ Date _________________

Investigator's signature____________________________________ Date _________________

Appendix B: Selected Websites

Advancing Women in Leadership (on-line journal)
http://www.advancingwomen.com/awl/awl.html

American Association of University Professors (AAUP)
http://www.aaup.org/AAUP/

American Association of University Women (AAUW)
www.aauw.org

American Institute of Mathematics (AIM)
www.aimath.org

American Mathematical Society (AMS)
www.ams.org

Association for Women in Mathematics (AWM)
www.awm-math.org

Association for Women in Science (AWIS)
www.awis.org

Commission on Professional in Science and Technology (CPST)
http://www.cpst.org/

Committee on Women in Science, Engineering, and Medicine (CWSEM)
http://www7.nationalacademies.org/cwsem/index.html

International Center for Research on Women (ICRW)
http://www.icrw.org/

Mathematical Association of America (MAA)
www.maa.org

National Council for Research on Women (NCRW)
http://www.ncrw.org/

National Physical Science Consortium (NPSC)
www.npsc.org

National Women's Studies Association (NWSA)
http://www.nwsa.org/

Office of Women in Higher Education
http://www.acenet.edu/AM/Template.cfm?Section=OWHE

Quality Education for Minorities in Mathematics, Science and Engineering Network (QEM)
http://qemnetwork.qem.org/

Women in Engineering Program Advocates Network (WEPAN)
www.wepan.org

Women in Higher Education (WiHE)
http://www.wihe.com/default.jsp

Appendix C: Leading US doctorate granting mathematics departments by percentage of women doctorates

	Universities	1980-1981 to 1989-1990			1995-1996 to 2002-2003		
		% Women	Total Women Doctorates	Total Doctorates	% Women	Total Women Doctorates	Total Doctorates
1	Illinois State University	54.5	6	11	56.00	14	25
2	Oklahoma, University of	41.7	5	12	43.33	13	30
3	Memphis State University	38.9	7	18			
4	Adelphi University	38.5	5	13			
5	Missouri, University of (Rolla)	38.5	5	13			
6	American University	36.0	9	25	55.56	15	27
7	Florida State University	35.3	6	17			
8	Massachusetts, University of (Amherst)	34.1	15	44			
9	Auburn University	34.8	8	23			
10	Lehigh University	33.3	7	21	54.17	13	24
11	South Carolina, University of	29.2	7	24			
12	Texas, University of (Arlington)	27.3	9	33			
13	Dartmouth College	28.6	6	21	52.38	11	21
14	Carnegie Mellon University	28.3	13	46			
15	Kansas State University	27.3	6	22			
16	Northern Colorado, University of				56.52	13	23
17	Syracuse University				53.13	17	32
18	Rhode Island, University of				52.17	12	23
19	Western Michigan, University				48.28	14	29
20	Rice University*				45.45	20	44
21	Colorado, University of (Boulder)				43.75	14	32
22	Cincinnati, University of				43.75	7	16

23	Nebraska, University of (Lincoln)				41.27	26	63
24	New Mexico, University of				40.54	15	37
25	Boston University				40.00	22	55
26	Washington State University				40.00	12	30
27	Washington, University of*				40.00	12	30
28	Colorado State University				40.00	10	25
29	Wesleyan University				39.13	9	23
30	Rensselaer Polytechnic Institute				39.02	16	41
31	Emory University				38.24	13	34
32	Oregon, University of				37.50	15	40
33	Duke University				37.50	12	32
34	Bowling Green State University				37.50	12	32
35	Vanderbilt University				37.14	13	35

* Applied Mathematics Departments

(Jackson, 1991, 2004)

Appendix D: Participants in the AIM Workshop

Arizona State University	Spelman University
Carnegie Mellon University	University of Arizona
George Washington University	University of California – Berkeley
North Carolina State University	University of California – San Diego
Ohio State University	University of Iowa
Rice University	University of Nebraska – Lincoln
Rutgers University	University of Northern Texas

(Herzig et al, 2006)

Appendix E: Top Schools in producing women with graduate degrees in mathematics

Bryn Mawr College	Stevens Institute of Technology
Florida Atlantic University	Stony Brook University
George Washington University	University of Tennessee
Mississippi State University	Tulane University
New Jersey Institute of Technology	University of Delaware
Dartmouth College	University of Illinois – Chicago
Howard University	University of New Hampshire
Rice University	University of Virginia
Southern Methodist University	Wayne State University

http://graduate-school.phds.org/

Appendix F: Possible University Participants

UMD	Location (See Region Map Appendix H)	Public/Private [a]	Size of School [a]	Graduate Program Description [b]
1	Northeast	Private	Medium	Doctoral, STEM dominant
2	West	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
3	Southeast	Private	Large	Comprehensive Doctoral, with Medical and Veterinary
4	Central	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
5	West	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
6	Northeast	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
7	West	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
8	Central	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
9	West	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
10	Central	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
11	Central	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
12	West	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
13	Northeast	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
14	Northeast	Private	Large	Comprehensive Doctoral, with NO Medical and Veterinary
15	Central	Private	Medium	Comprehensive Doctoral, with NO Medical and Veterinary
16	Northeast	Private	Medium	Comprehensive Doctoral, with NO Medical and Veterinary

17	Southeast	Public	Large	Doctoral, STEM dominant
18	Northeast	Private	Medium	Comprehensive Doctoral, with NO Medical and Veterinary
19	Southeast	Private	Large	Comprehensive Doctoral, with Medical and Veterinary
20	Southeast	Private	Large	Comprehensive Doctoral, with Medical and Veterinary
21	Northeast	Private	Medium	Doctoral, STEM dominant
22	West	Public	Large	Doctoral, STEM dominant
23	Northeast	Public	Large	Comprehensive Doctoral, with NO Medical and Veterinary
24	Northeast	Public	Large	Comprehensive Doctoral, with Medical and Veterinary
25	Central	Public	Large	Comprehensive Doctoral, with Medical and Veterinary

Note: a -- These statistics are all taken from the same source: A college guide book published in 2008.
b -- According to the Carnegie Foundations at http://www.carnegiefoundation.org/classifications/index.asp?key=807

Appendix G: Letter of Invitation for Phase I and Phase II

1890 Main Campus Drive
NCSU Box 7249
Raleigh, NC 27606
(919) 607 6996

Director of Graduate Programs or Administrative Equivalent
Department of Mathematics
Box 8205 North Carolina State University
Raleigh, NC 27695

To Whom It May Concern:

I am writing to invite you to participate in a research study. The purpose of the study is to examine the practices of mathematics departments with a high percentage of women graduating with doctoral degrees. Your department is one of several in the United States that has been successful in producing women mathematicians. The main goal of the research is to identify what practices, policies, and departmental environments encourage and influence women to attend and graduate. Participation in this research will benefit other mathematics departments and help to diversify the mathematics community.

There are three phases to this study. This letter is to invite to participate in Phases I and II. The first phase involves the collection of public and departmental documents used within your mathematics department, and a phone interview with the Director of Graduate Programs or administrative equivalent. The second phase of the study is an online graduate student questionnaire open to all masters and doctoral students. If you choose to participate, then you will receive in aggregate from the results of the graduate student survey as well.

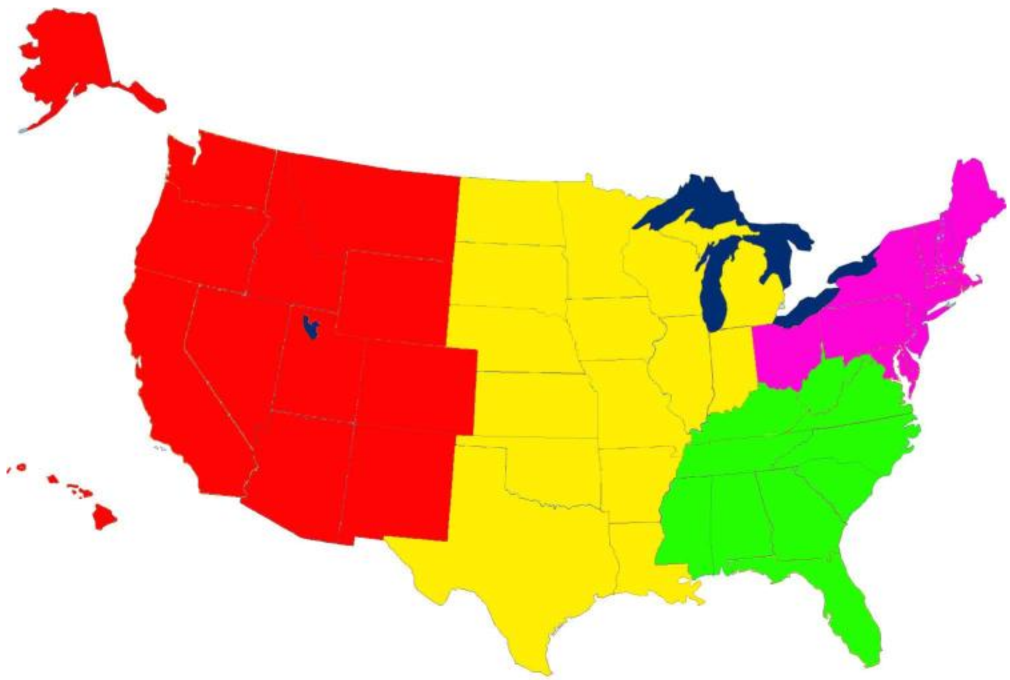
Only a subset of the university mathematics departments that participate in Phases I and II will be invited to participate in Phase III. If your university is selected, Phase III of the study will take place during the spring semester of 2009. During this time, I will visit three university campuses and the mathematics department for 2-3 weeks. While visiting, I will interview both faculty members and graduate students and attend departmental functions, as appropriate.

You may choose to participate in only the first and/or second phases without indicating a willingness to participate in Phase III.

If you are willing to be a participant in this research study or would like further information before making a decision, please do not hesitate to contact me. I look forward to hearing from you.

Thank you,
Amanda Lambertus, PhD Candidate in Mathematics Education
North Carolina State University
ajlamber@ncsu.edu

Appendix H: Regional Map of the United States



Red – Western Region

Yellow – Central Region

Green – Southeastern Region

Pink – Northeastern Region

Appendix I: Website Evaluation Rubric given to Evaluators

Website Evaluation Rubric

This rubric is to be used for looking at ***graduate mathematics programs and departments***. This means that the evaluator should focus primary on these web pages. However, some information and descriptors will be found on main department pages, such as the mathematics department homepage as well as prospective graduate student pages, people pages, research pages, and links.

	Element	Descriptors	Additional Information	Rating
1. Welcome	1.1Color and Font	1.1.1 **Easy to read** 1.1.2 Background does not interfere with the text 1.1.3 Consistent design/style gives the site coherence 1.1.4 Minimal clutter	**1.1.1 Easy to read** – Font is big enough to see clearly must be no smaller than 12, color of font is also easy to see. Yellow font would not be a good choice	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two or three of the descriptors are missing 0 – all are missing

	1.2 Language	1.2.1 Avoids generic masculine pronouns 1.2.2 Uses active rather than passive voice (80% of the time) 1.2.3 Uses **everyday language** to convey goals	**1.2.3 Everyday Language** – does not contain jargon specific to mathematics, does not use undefined acronyms	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing 0 – all are missing
	1.3 Pictures	1.3.1 Photos include graduate students interacting with faculty members in classrooms and labs 1.3.2 Uses photos that **humanize** the site and make it more aesthetically attractive 1.3.3 Include photos of women and minorities in positions of leadership	**1.3.1 Humanizing** the site – images of people working together, images of people who appear to be enjoying what they are doing	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing, or the images from 1.3.1 and 1.3.2 are of males from non-underrepresented groups 0 – all are missing, there are no images on the website, or images are only of buildings or places

	1.4 Well Organized and Functional	1.4.1 **Easily located information** 1.4.2 Easy to find links 1.4.3 Organized tabs	**1.4.1 Easily located information** – focus on information about the graduate program, degree requirements, application processes, and administrative information	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing 0 – all are missing
2. Navigation	2.1 Accuracy	2.1.1 The site provides or invites **diverse perspectives** (concerning mathematics, such as pure or applied perspectives). 2.1.2 Site does not contain obvious content errors or omissions 2.1.3 Date of last revision is given on **relevant pages** (80% of the time) 2.1.4 The **information** that is time sensitive appears to be updated regularly	**2.1.1 Diverse Perspectives** – in this instance diverse perspectives is referring to the types of mathematics that can be learned. If the site provides multiple perspectives or opportunities for learning mathematics in interdisciplinary settings than the criteria is met. If the site only uses a tightly defined single view for understanding mathematics the criteria is not met. Also having multiple areas in which students can conduct research meets the criteria **2.1.3 Relevant pages** are those that are updated regularly, such as exam schedules, course schedule pages, scholarship pages, or pages that contain information which have deadlines.	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two or three of the descriptors are missing 0 – all are missing

			2.1.4 Information should not include internships for 2007, or applications and information to things that are no longer available	
	2.2 Accessibility	2.2.1 **Links** work and are all functional, no coding errors 2.2.2 **Contact information** for the application process is available and easy to find 2.2.3 Convenient access to **departmental information** 2.2.4 Links or Tabs for home page remain on all sub-pages	**2.2.1 Links –** allowing for up to three links to outside organizations or resources that may not work. **2.2.2 Contact Information** is provided for the application process, where to send information, who to ask questions of and find information. **2.2.3 Departmental information** for department or relevant people within the department, such as directors of graduate study, application contacts…	3 – all descriptors are present 2 – one or two of the descriptors is missing 1 – three or four of the descriptors are missing 0 – all are missing
3. Inclusion	3.1 Diversity-Friendly Links	3.1.1 Includes links to relevant **internal organizations**/resources at least three must be present 3.1.2 Includes links to	**3.1.1** Some **internal organizations** may include: the graduate school, graduate student organizations within the university, student chapters of	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing

		relevant **external organizations**/resources at least three must be present 3.1.3 Includes links to organizations/resources for **women and minorities** at least one must be present	Mathematics Association of America or American Mathematical Society, Association of Women Faculty links, student handbook, Pi Mu Epsilon Chapter, computer resources, dissertation information … **3.1.2 External Organizations** may include, Mathematics Association of America, American Mathematical Society, Society for Industrial and Applied Mathematics, mathematical journals, National Science Foundation, National Institute of Health **3.1.3** Links for **women and minorities** in math would include…Association of Women Faculty, Association of Women in Mathematics	0 – all are missing
	3.2 Relevance and Appropriateness	**3.2.1** Site provides appropriate information for graduate students	**3.2.1** For example, course schedules, grants, funding information, exam schedules and information, Latex coding	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are

		3.2.2 Site provides appropriate information for faculty 3.2.3 Site includes availability for contacting the webmaster	information, seminar schedules, graduate handbook, career center. These may be found on the main pages or linked to other pages. At least 5 must be present **3.2.2** The site provides email and contact information for the administration, up to date information on graduation requirements, course schedules, graduate handbook, links to the graduate school, relevant paperwork, seminar schedules, promotion policies. These may be found on the main pages or linked to other pages. At least 5 must be present	missing 0 – all are missing
4. Aspirations	4.1 Commitment to Diversity, Multiculturality	**4.1.1** Signal a commitment to diversity (gender and ethnic) from department rather than a piggyback from the university **4.1.2** Commitment to diversity language should not be segregated on pages dedicated to the recruitment/retention of	**4.1.1** If the department has its own diversity website it meets the criteria for 4.1.1, if the department refer you to the university diversity site, then it does not meet the criteria. **4.1.2** You should be able to find reference to diversity (gender and ethnic) throughout the website	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two or three of the descriptors are missing 0 – all are missing

		women and minorities, but should appear throughout the website 4.1.3 Site is free of material that may be oppressive to one or more groups of students **4.1.4** Signal commitment to supporting graduate students at all levels	**4.1.4** This includes funding for all types of graduate students regardless of SES, evidence of the different ways the department may fund students	
	4.2 Science and Technology in the Real World	**4.2.1** Includes discussions of jobs and activities of graduates and/or those in the profession 4.2.2 includes information about how the profession and its members contribute to the welfare of society/ the physical environment and/or the wellbeing of people **4.2.3** Outreach programs **4.2.4** Show women and minorities in active roles in photos engaged in the field	**4.2.1** This may include noting what types of careers past graduates have received, what institutions they accepted positions at. **4.2.3** This may include k-12 programs as well as other types of programs implemented in the community **4.2.4** Engaged in the field means presenting posters, giving talks, working with other in research within the main department pages…	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two or three of the descriptors are missing 0 – all are missing **4.2.4** Award ½ point for photos of women and minorities that are restricted to separate pages such as those for Women in Math Days Count up missing descriptors and look at rubric, then add back the ½ points

	4.3 Characterizing Female and Male Students as Professionals	4.3.1 Assures that photos and textual characterizations of women and men are **harmonized** throughout the website 4.3.2 Includes names and forms of address, photos, biographical information, descriptions of research for faculty members (80% of the time) 4.3.3 Includes names, address, photos of graduate students (80% of the time) 4.3.4 Professional experiences for graduate students are evident	**4.3.1 Harmonized** Photos do not show only men in dominate or leadership positions. **4.3.4** It may also include graduate student conference or seminars in which the students get to participate as members of the group rather than simple observers. This may also include seminars and colloquia that the students and faculty participate in together.	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two or three of the descriptors are missing 0 – all are missing **4.3.2** award ½ point if one of the 5 items are missing **4.3.3** award ½ point if one of the 3 items are missing Count up missing descriptors and look at rubric, then add back the ½ points
5. Statements	5.1 **Mission Statement** summary describing the aims, values, and overall plan of a mathematics	5.1.1 **Explicitly stated** **5.1.2** located on the prospective student pages or linked from the homepage 5.1.3 Uses **everyday language** to convey goals	**5.1.1 Explicitly Stated** – headed with a title such as Mission of the department, clearly indicated **5.1.2** – may be located within the text describing the department either in a description of the department or on a prospective student page	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing 0 – all are missing

	department	The mission statement must be relevant to the graduate program. It can most often be found on prospective student pages.	**5.1.3 Everyday Language** – does not contain jargon specific to mathematics, does not use undefined acronyms	
	5.2 **Diversity Statement** Summary describing the aims, values, and overall plan for diversifying the mathematics department This does not mean, "the department is diverse in terms of faculty backgrounds or research areas"…	5.2.1 **Explicitly stated** **5.2.2** Located on the homepage or linked from the homepage 5.2.3 Uses **everyday language** to convey goals The diversity statement can be an over-arching goal for the department as a whole, and not be limited to the graduate program. This statement may be found on main department web pages.	**5.2.1 Explicitly Stated** – headed with a title such as Mission of the department, clearly indicated **5.2.2** – may be located within the text describing the department either in a description of the department or on a prospective student page **5.2.3 Everyday Language** – does not contain jargon specific to mathematics, does not use undefined acronyms	3 – all descriptors are present 2 – one of the descriptors is missing 1 – two of the descriptors are missing 0 – all are missing If the department provides a link to the university diversity statement then score a 0

Appendix J: Form for Website Evaluators to Complete

Department	
Website (URL)	
Reviewers Name	
Date Reviewed	

	Element	**Descriptors**	**Comments** **List the descriptors that are missing**	**Your Score**
1. Welcome	1.1Color and Font	1.1.1 **Easy to read** 1.1.2 Background does not interfere with the text 1.1.3 Consistent design/style gives the site coherence 1.1.4 Minimal clutter		
	1.2 Language	1.2.1 Avoids generic masculine pronouns 1.2.2 Uses active rather than passive voice (80% of the time) 1.2.3 Uses **everyday language** to convey goals		
	1.3 Pictures	1.3.1 Photos include graduate students interacting with faculty		

		members in classrooms and labs 1.3.2 Uses photos that **humanize** the site and make it more aesthetically attractive 1.3.3 Include photos of women and minorities in positions of leadership		
	1.4 Well Organized and Functional	1.4.1 **Easily located information** 1.4.2 Bulleted or easy to find links 1.4.3 Organized easy find tabs 1.4.4 **Creates as good first impression**		
2. Navigation	2.1 Accuracy	2.1.1 The site provides or invites **diverse perspectives** (concerning mathematics, such as pure or applied perspectives). 2.1.2 Site does not contain obvious content errors or omissions 2.1.3 Date of last revision is given (at least on the main page) 2.1.4 The **information** that is time sensitive appears to be updated regularly		
	2.2 Accessibility	2.2.1 Links work and are all functional, no coding errors 2.2.2 **Contact information** is		

		available and easy to find 2.2.3 Convenient access to departmental information 2.2.4 Links or Tabs for home page remain on all sub-pages		
3. Inclusion	3.1 Diversity-Friendly Links	3.1.1 Includes links to relevant **internal organizations**/resources 3.1.2 Includes links to relevant **external organizations**/resources 3.1.3 Includes links to organizations/resources for **women and minorities**		
	3.2 Relevance and Appropriateness	**3.2.1** Site seems relevant to graduate students needs **3.2.2** Site seems relevant to faculty needs 3.2.3 Site includes availability for contacting the webmaster		
4. Aspirations	4.1 Commitment to Diversity, Multiculturality	**4.1.1** Signal a commitment to diversity (gender and ethnic) from department rather than a piggyback from the university **4.1.2** Commitment to diversity language should not be segregated on pages dedicated to the recruitment/retention of women and minorities, but should		

		appear throughout the website 4.1.3 Site is free of material that may be oppressive to one or more groups of students **4.1.4** Signal commitment to supporting graduate students at all levels		
	4.2 Uses Science and Technology in the Real World	**4.2.1** Includes discussions of jobs and activities of graduates and/or those in the profession 4.2.2 includes information about how the profession and its members contribute to the welfare of society/ the physical environment and/or the wellbeing of people **4.2.3** Outreach programs **4.2.4** Show women and minorities in active roles in photos engaged in the field		
	4.3 Characterizing Female and Male Students as Professionals	4.3.1 Assures that photos and textual characterizations of women and men are **harmonized** throughout the website 4.3.2 Includes names and forms of address, photos, biographical information, descriptions of		

		research for faculty members (80% of the time) 4.3.3 Includes names, address, photos of graduate students (80% of the time)		
5. Statements	5.1 Mission Statement	5.1.1 Explicitly stated 5.1.2 located on the homepage or linked from the homepage 5.1.3 Uses **everyday language** to convey goals		
	5.2 Diversity Statement	5.2.1 Explicitly stated 5.2.2 Located on the homepage or linked from the homepage 5.1.3 Uses **everyday language** to convey goals		

Appendix K: DGP Phone Interview Protocol (Phase I)

1. Please describe the climate of your department

    a. Relationships among graduate students
    b. Relationships among faculty members
    c. Relationships between graduate students and faculty
    d. Collegiality among faculty and graduate students

2. Your department has been identified as one with a successful record of producing women mathematicians. Why do you think that is?

    a. What would you say are the strengths of your department that may be leading to that success?
    b. What are the weaknesses of your department?

3. Please describe the diversity in your department.

    a. Faculty diversity
    b. graduate students diversity
    c. undergraduate student diversity

4. Can you tell me how you recruit your graduate students?

    a. What do you see as the strengths of this type of recruitment?
    b. What do you see as the weaknesses of this type of recruitment?

5. Can you tell me about your departments methods for screening graduate school applicants? Does gender ever factor into that process or affect decisions to accept an applicant?

6. Does your department or college have any optional or mandatory diversity training for its faculty? Tell me about it.

7. What sort of academic or research opportunities or financial support do you offer your graduate students (other than TAs)? How are students selected to receive such opportunities or financial support?

8. What sort of support is offered to students who are having trouble or thinking about leaving the program?

9. Do you see your department as a community? In what ways?

Appendix L: Graduate Student Online Questionnaire (Phase II)

Graduate Student Questionnaire

1. What is your gender?
    a. Male
    b. Female
2. Which program are you in enrolled in?
    a. Pure Mathematics
    b. Applied Mathematics
    c. Statistics
    d. Other
3. What degree level are you currently seeking?
    a. Masters Degree
    b. Doctorate Degree
4. How many years have you been in the mathematics graduate program at your university?
    a. Less than one
    b. 1-2
    c. 2-3
    d. 3-4
    e. 4-5
    f. More than 5
5. Are you currently enrolled…(check one)
    a. Full time
    b. Part time
6. What is your field of interest for your thesis or dissertation?
7. If you are working on a doctorate degree, did you complete you masters degree at your current university? (check one)
    a. Yes
    b. No

    Why did you choose to stay here or to leave a different university?
8. Why did you choose to apply and accept admission to this university? (check all that apply)
    a. Funding opportunities
    b. Family responsibilities
    c. Location of university
    d. Reputation of program
    e. Reputation of particular faculty member
    f. Reputation of mathematics department
    g. Collegiality among faculty and graduate students
    h. Recommendation from
        i. Former graduate students

    ii. Current graduate students
    iii. Faculty member at another institutions
    iv. Other

  i. Recruited to program (Please describe efforts made to recruit you in the text box)
  j. Size of university
  k. Other

9. Please provide any additional information that you feel would help me understand why you chose to become a member of your current department.
10. Would you recommend this program or department to prospective women applicants interested in studying graduate mathematics?
    a. Yes
    b. No

    Why? Or Why not?
11. Please describe some memorable experiences you have had within your department.
    a. Experiences with faculty
    b. Experiences with graduate students
    c. Positive and negative experiences
12. How would you describe the climate of your department?
13. If you could change one thing about your department what would it be and why?
14. Which of the adjustments in going from undergraduate to graduate study have you found to be the most difficult? Did you expect to have to make these adjustments? Please explain.
15. In terms of your decision to come to this program, which of the following would you agree with the most? Please answer and then explain.
    a. Feel even more strongly that it was a good decision
    b. Feel satisfied with your decision
    c. Feel unsure if it was the right decision
    d. Regret your decision

16. Would you be willing to participate in a follow up interview? If yes, please provide your contact information below.

Appendix M: Letter of Invitation for Graduate Student Online Questionnaire (Phase II)

1890 Main Campus Drive
NCSU Box 7249
Raleigh, NC 27606
(919) 607 6996

Department of Mathematics
Box 8205 North Carolina State University
Raleigh, NC 27695

Dear Graduate Student,

I am writing to invite you to participate in a research study. The purpose of the study is to examine the practices of mathematics departments with a high percentage of women graduating with doctoral degrees. Your department is one of several in the United States that has been successful in producing women mathematicians. The main goal of the research is to identify what practices, policies, and departmental environments encourage and influence women to attend and graduate. Participation in this research will benefit other mathematics departments and help to diversify the mathematics community.

If you would like to participate in the research project, please complete the Graduate Student Online Questionnaire at the following link, website. Your name will not be recorded unless you provide contact information stating you would be willing to participate in an interview at a later date.

If you are willing to be a participant in this research study and would like further information before making a final decision, please do not hesitate to contact me. I look forward to hearing from you.

Thank you,
Amanda Lambertus, PhD Candidate in Mathematics Education
North Carolina State University
ajlamber@ncsu.edu

Appendix N: Graduate Student Interview Protocol (Phase III)
Participant Number:
Participant First Name:
Date of Interview:

INTRODUCTION

Hello ... thank you for agreeing to talk with me. I am conducting a study that is designed to help me understand graduate student's perceptions related to a graduate mathematics community of practice and learning. I am especially interested in your decisions about whether to pursue careers or advanced degrees in mathematics. With your help, I want to understand what kinds of things influence your beliefs and perceptions at different stages. For example, what types of information or experiences help you to decide what degree to pursue? What kinds of things did you think about when considering a potential career in mathematics and membership in the mathematics community? How do you view the community in which you are participating?

I have a list of questions I am going to discuss with you, but there may be things I do not think of or mention that you feel are important in trying to explain why you choose to pursue a mathematics doctorate and your current department. At the end, I will ask you if there is anything you want to add to the information I've asked.

Do you have any questions?

1. Tell me a little bit about yourself....
    a. Where are you in relation to your course work?
    b. Why did you choose this particular university?
    c. Did you complete a previous degree at this university?
        i. Why did you stay here, or choose to leave your other university?
    d. What led you to pursue an advanced degree in mathematics?
    e. What is your field of study? Why are you interested in this subject?

2. Tell me about being a student in this program/department.

3. Please describe the climate of your department
    a. Relationships among graduate students
    b. Relationships among faculty members
    c. Relationships between graduate students and faculty
    d. Collegiality among faculty and graduate students

4. Your department has been identified as one with a successful record of producing women mathematicians.
    a. Why do you think that is?
    b. Did this impact your decision to attend this particular school?
    c. Were you aware of their record prior to attending?

    d. What would you say are the strengths of your department that may be leading to that success?
    e. What are the weaknesses of your department?
5. Looking back, can you describe how you decided to pursue a Ph.D. in mathematics, describe any experiences that may have influenced you along the way?

6. Have you changed your mind about your area of study? Tell me about it …

7. Are you currently employed by the mathematics department? Tell me about your responsibilities.
    a. Who do you ask or go to if you have trouble or need help?
    b. What other opportunities for support are available within your department?
    c. What kinds of experiences or opportunities are available to help supplement your courses and prepare you for a career in mathematics?
    d. In what ways do you feel you have been supported in your pursuit prior to attending graduate school? (during graduate school)

8. How does your department prepare students for different types of careers?
    a. What types of careers/jobs are you considering in the future? Why?

9. Please describe some experiences you have had with faculty members
    a. What have been your experiences with the faculty advisors?
    b. How did you identify and seek out a dissertation committee chair?
    c. From whom did you seek advice?

10. What, if any, challenges do you feel you have had to overcome to be successful in your field?

11. Who do you seek help from?
    a. For course work, dealing with stress, managing time…

12. Do you think that your gender has affected your pursuit of an advanced degree, if yes, in what ways?

13. What advice would you give to a young woman or man just starting her graduate degree in mathematics?

14. What experiences did you have as a graduate student that might influence your interactions with graduate students in the future?
    Will you try to foster similar opportunities for your graduate students?

15. If you had the opportunity, what would you change about your graduate experience?
    a. About the department?

16. Is there anything you would like to add?
Thank you for your time

Appendix O: Faculty Member Interview Protocol (Phase III)

1. Please describe how you decided to become a mathematician.
    a. What were some of the experiences that influenced you along the way?
    b. Discuss the social and cultural variables that you think were significant through your personal and professional development.

2. How long have you held your current position?
    a. What factors did you consider when accepting a position (or choosing to stay) at your current institution?
    b. Can you relate some positive things about the department that will keep you here in the future?
    c. What is unique within your department?

3. Tell me about being a faculty member in this department.
    a. How does this compare to previous positions you have held?
    b. Describe the climate of your department.

4. What experiences did you have as a graduate student that have influenced your interactions with current graduate students?
    a. Do you try to foster similar opportunities for your graduate students?

5. What sort of academic or research opportunities or support do you offer your graduate students?
    a. What sort of professional relationships are there between graduate students and faculty members?

6. Describe the culture or environmental dynamics of your department.
    a. Do you consider your department to be supportive and collaborative among faculty members?
    b. Among Graduate Students?
    c. Between faculty and graduate students?

7. Highlight some of the hallmarks of your mentoring style.

8. What do you perceive are the most important things that graduate students walk away from their program knowing?

9. Are you aware your department has been identified as one with a successful record of producing women mathematicians?. What do you think are some of the factors that might contribute to this record?
    a. What would you say are the strengths of your department that may be leading to that success for women?

b. What are some the weaknesses that women may struggle within your department?

10. Do you see your department as a community? In what ways?

Appendix P: New Student Questionnaire Protocol (Phase III)

1. What is your gender?

2. Are you beginning a master's program or PhD program?

3. Where did you earn your bachelor's degree?

4. Where did you earn a master's degree (if applicable)?

   In answering the following questions, please consider your experiences since you arrived to begin your program of study at NC State.

5. Describe your impression of the collegiality among faculty and graduate students within the department.

6. What activities or events did you attend that were sponsored by the department? How were these activities or events helpful in making your transition to graduate school?

7. What efforts has the department made to make you feel welcome?

8. What are some things that you like/enjoy about the department?

9. Have you had any disappointing moments within the department thus far? Explain.

10. What are your expectations for the upcoming year, in relation to graduate student and faculty relationships, coursework, advising, and TA or RA responsibilities?

11. Describe any experiences *outside* the department that were particularly impressionable (positive or negative) during these first few weeks?

Appendix Q: Graduate Student Interviews Containing Characteristics and Descriptors

<table>
<tr><th colspan="2">Characteristic</th><th>Descriptor</th><th></th></tr>
<tr><td rowspan="13">Attractants</td><td rowspan="5">Personal</td><td>Program recommended
PhD program F9
Undergraduate advisors are tremendously influential</td><td>F6, F13, F1, F10, F2, F4, F7 M2, M1, M3, F3</td></tr>
<tr><td>Geographic location
Also in relation to jobs</td><td>F2, F4, M2, F3</td></tr>
<tr><td>Family obligations/responsibilities</td><td>F6, F9, F2, F5, F12</td></tr>
<tr><td>Limited options in graduate programs</td><td></td></tr>
<tr><td>Satisfaction with choice of program
Makes sense that they are all satisfied with the program they have been successful.
Dissatisfaction usually occurred in the first semester with overwhelming feelings involved in starting a doctoral program.</td><td>F6, F13, F1, F9, F10, F2, F5, F4, F7, M1, M2, M3, M4</td></tr>
<tr><td rowspan="4">Universal</td><td>Diversity of research
Lots of options
Leave options open for research</td><td>F13, F2, F6, F1, F7, M4</td></tr>
<tr><td>Size of department</td><td></td></tr>
<tr><td>Reputation of university and/or department</td><td>F6, F1, F9, M1</td></tr>
<tr><td>Faculty areas of research</td><td>F5, M1</td></tr>
<tr><td rowspan="2">Both</td><td>Financial Aid</td><td>F6, F4, F7, F5, M1, M4, F12, F8</td></tr>
<tr><td>Recruitment
Department puts effort into their recruiting
Campus visits are a factor in choosing to come here</td><td>F13, F1, F10, F2, F4, F7, M3, M4, F8, F3</td></tr>
<tr><td colspan="2" rowspan="3">Environment</td><td>Faculty value success of students
Students feel like the faculty care about them
Climate is conducive to everyone moving forward</td><td>F4, F9, F10, F2, F7, F5, M1, M3, F8, F3</td></tr>
<tr><td>Friendly and welcoming
Faculty are friendly and chat with students
Faculty are also all business but welcoming
Comfortable environment, Safe
Close Knit</td><td>F13, F1, F9*, F10, F7, F5, M1, M2, M3, M4, F3, F8, F12</td></tr>
<tr><td>Perceptions of gender issues</td><td>F6, F13, F1, F9,</td></tr>
</table>

	• Don't have to prove anything if you are a woman • Genders are not treated differently • No negative experiences	F10, F2, F5, M1, M3, M4, F8, F3
	Gender diversity among faculty and students • F9 looked at website to see how many women were in the faculty and student body	F13, F9, F10, F2, F7, M1, M3, F12, F3
	Open and supportive faculty • Knowledgeable • Communicate well • Want you to have a life	F6, F13, F1, F9, F10, F4, F7, F5, F3
Academic Support	Colloquia and seminars [b] • Seminars on technical information, using MATLAB, or LATEX • Seminars are areas in which you want to grow	F6, F10, M3, M4, F8
	Teaching and professional development (voluntary and in-voluntary) • Encouraging participation in professional organizations • Department emails about opportunities for internships and research experiences • Grant writing experience • 18 grad credits in order to teach a class • Present at conferences	F6, F13, F1, F9, F10, F2, F5, M1, M2, M3, M4, F8, F3
	Resources for growth, i.e. Library • Graduate school seminars • Travel $ for conferences • Publish Early	F1, F9, F2, M4
	Exam practices • Old ones are available from secretary • Same professor for both courses in the sequence • Students able to tailor their programs and exams to their needs, wants and desires, connected to their research interests • Choice on when to take	F6, F13, F1, F10, F4, F5, M1, M3, M4, F3
	Alignment of Master's and PhD • Gives an out if you are not happy • Most students did not consider it	F13, F10, F7, F5, M4, F8
	Financial aid [b]	F13, F1, F10, F4,

	• Faculty don't want students to have to worry about it • STEM TA • Ethnic minority scholarships • Vagina Scholarships *Some gender issues with female based scholarships, men don't understand why the preferential treatment.(as reported by the women)*	M1, M3, M4
	Diversity of research [b] • Easy to find an area that interests you • M2 – freedom to choose own interests to pursue • M1 – gives you a breathe of knowledge	F5, F12, F8, F3
	Office space of the graduate students [b]	
	Collaboration between disciplines	F7, M1, M3, F8, F3
	Advisor role [b] • Supportive • Network • Preparation for career • Good at asking questions instead of giving answers • Guide research	F6, F10, F2, F7, F5, M1, M2, M3,M4, F12, F8, F3
	Faculty accessibility [b]	F4, F7, F5, M1, M3, M4, F8, F3
	Students involved in research early in career (*even if they are not RAs*)	F6, F13, F1, F9, F10, F5, F4, F7, M1, M2, M3, F12, F3
Interactions	Office space of the graduate students [b] • Not all together • Tend to move a lot	F6, F4, M4, F8, F3
	Collaboration between graduate students [b] • Faculty encourage this • Feel that students need to have experience working in teams and with others	F6, F13, F1, F10, F7, F5, M3, M4
	Colloquia and seminars [b] • Experience presenting, asking questions, and answering questions • Faculty and students engage in conversations and share ideas	F6, F10, F7, M3, M4
	Social events within the department	F4, F7, F5, M1, M3, F8
	Advisor role [b]	F6, F9, F10, F2, F7,

	• Find a person you can work with • Choose advisor to match personality • Suggests classes pertinent to research • Supportive, guiding • Extra time on career preparation	M1, M2, M3, M4, F8, F3
	Faculty accessibility [b] • Helpful • Want to help students understand math	F13, F4, F7, F5, M1, M3, F10, M4, F12
	Regularly scheduled department teas	F5, F7, F12
	Common spaces • Impromptu conversations in the mail room	F1, F13, F5
Relationships	Office space of the graduate students [b]	F1, F9, F4, M4, F12, F8, F3
	Collaboration between graduate students [b] • Students don't feel the need to compete • Supportive of different learning curves • Share notes from different classes • Share exams • Rely on each other to survive	F6, F13, F1, F9, F10, F4, F7, M1, M3, M4, F8, F3, F13
	Social activities outside department	F13, F1, F10, F4, F7, F5, M3, M4, F8
	Informal mentoring of younger students from more senior students • Mentor on classes, professors, advisors • Support system for new students and experienced students	F6, F13, F1, F9, F7, M3, F12, F8

Appendix R: Community of Practice by Department