

Rethinking Alternative Models for Increasing Female Participation in Graduate Mathematics

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Abstract

This paper examined successful models associated with the increased participation of women in doctoral level mathematical sciences. The study applied professional socialization theory to analyze departmental policies and practices and their impact on the professional socialization of women in doctoral level mathematics. Through qualitative intrinsic case studies, existing¹ and primary data² were obtained by interviewing faculty and female graduate students from two university mathematics departments, in the U.S. Data were obtained from 61 and 25 participants, respectively. The results revealed that departmental leaders and faculty members: reached out for female students in the mathematics pipeline and took them through anticipatory and organizational socialization processes; applied a holistic approach in recruiting and admitting women; restructured the existing policies; facilitated female students' participation in the community of practice and encouraged positive interactions with faculty and peers. In sum, provision of a supportive environment to all graduate students enhanced participation of women in mathematics.

Key words: Recruitment, Retention, Women, Mathematics, Policies, Professional Socialization

Section 1

Introduction

In the United States, women's participation in the doctoral level mathematical sciences has historically been lower than men's (Kirkman, Maxwell, and Rose, 2006). For instance, women earned 46% of bachelors' degrees awarded in mathematics in the U.S. in 1996 (National Science Foundation [NSF], 2002). In the following year, women made up only 24% of the nation's PhD's in mathematics (Henron, 1997). Women comprised 42% of masters' degrees in mathematics in 1998 (NSF, 2002). In 2000, women received 47% of bachelors' degrees, 45 % of master's degrees and 25% of PhD degrees awarded in mathematics in the United States (National Science Foundation 2002; Kirkman et al. 2004b, 2006; Gallagher and Kaufman 2005). Women earned 32% of PhDs in mathematics, in 2001-2002 (Loftsgaarden, Maxwell, and Priestly, 2003). A recent statistical profile of recipients of doctoral degrees awarded by departments in the mathematical sciences at U.S. universities during the academic year 2005-2006 reports that of the 552 U.S. citizens new doctoral recipients, 153 (27%) were women.

This problem of persistently having small numbers of women in mathematics, especially at the doctoral level, is of great concern to the mathematics community in the United States, if not to the nation in general (Bass, 2003; Chan, 2003; Herzig, 2004; Kirkman et al. 2006). This study examined two university mathematical science departments that have recently succeeded in increasing the numbers of women enrolling and graduating in doctoral level mathematical sciences. It concentrated on each department's policies as implemented, and as experienced by female graduate students. The study applied professional socialization theory and departmental policies and practices as lenses to determine the successful models that could be used to enable women make decisions to pursue mathematics at the doctoral level and persist until the completion of their degrees.

¹ Dr. Herzig, Assistant Professor, at the Department of Educational Theory and Practice at the University at Albany, obtained the existing data by conducting qualitative intrinsic case studies at the Departments of Mathematics at the Midwestern University (MU) and Applied Mathematics Department at Southwestern University (SU) in 2003-05. The title of the project: "Facilitating the Success of Female students and Students of Color in Doctoral Mathematics." Herzig's project involved the study of four doctoral mathematics programs that have made successful efforts in recruiting and retaining female students and students of color. The study was funded by the National Science Foundation under Grant No. 0346556.

² I analyzed the existing data from two departments (MU and SU) and conducted follow-up interviews (some of faculty and female graduate students I interviewed had participated in the previous study) at the two departments. The focus of the follow-up data collection was on women and not students of color.

Section 1.1

Rationale for professional socialization theory and policies and practices

Professional socialization is defined as the acquisition of knowledge, skills, and values necessary for a successful start to a professional career requiring an advanced level of specialized knowledge and skills; it serves as a driving influence that has significant impact on one's professional development (Weidman, Twale, & Stein, 2001). This study views a graduate student as an active individual who makes choices concerning how to react to the process of socialization within the context of departmental policies and practices; thus, assumed an interpretive approach to socialization that emphasizes human agency. Policy is defined as "the dynamic and value-laden process through which a political system handles a public problem (Fowler, 2000, p9). Public policy is conferred the status of "official tool of governance" (Sutton & Levinson, 2001, p3). This implies that policy is the work of "the authorities" (Sergiovanni, Burlingame, Coombs, & Thurston, 1999, p57; Fowler, 2000). In the classical model of decision making, the authorities (people in leadership positions) normally make decisions at a higher level and then pass them down the hierarchy (Miskel & Hoy 2001, p317). In this study, "the authorities" are the faculty, in particular, departmental chairs, and student recruiting chairs—who make and implement policy decisions in regard to the recruitment and retention of women in graduate mathematics.

Section 2

The study

Although studies have reported some of the major difficulties that women face in mathematics: incompatible relationships with their advisors (Girves & Wemmerus, 1988); victims of discrimination (Becker, 1990) and, feelings of isolation due to too little contact between faculty and students (Herzig, 2002; Lovitts, 2001), seldom are departmental policies and professional socialization processes examined together. Yet, the two concepts are integral parts of higher education. The present study represents a major paradigm shift from the previous studies that focused on factors influencing women's under-participation to the present focus on reasons for their success. This study focused on the two universities—the Midwestern University (MU)³ and the Southwestern University (SU),—because they are among the leading U.S. doctorate-granting mathematics departments that have reported increased numbers of female students in mathematical sciences in recent years. These two departments—MU and SU—reported the highest percentage of female students doctorates for the period 1995 through 2003 with an average of 41% and 45 % respectively (Jackson, 2004) compared to the national rate of 27% (Kirkman et al., 2007). Of note is that during the earlier periods, both universities had low percentages of PhDs earned by female students. Yet, the gender composition of the two departments' PhD recipients changed in the late 1980's. Therefore, the main concern of this study was to examine the models these two departments applied to attract and retain women in doctoral level mathematical sciences.

Section 2.1

Theoretical framework

The theoretical framework for this study hinges on the premise that certain departmental policies and practices in university settings impact the professional socialization (Weidman et al. 2001), and increase the recruitment and retention of female students in doctoral level mathematical sciences. That, while faculty members design and implement policies that affect recruitment and retention of female graduate students, female graduate students experience implemented policies and practices during anticipatory and organizational socialization processes, hence choose to apply and persist until the completion of their degrees. Anticipatory socialization comprises facets of socialization a student experiences before entering the doctoral program. Organizational socialization involves processes that occur after entering the graduate program (Van Maanen & Schein, 1979). As students experience both anticipatory and organizational socialization processes, they develop professional identity, hence persist until the completion of degree. Both socialization processes (anticipatory and organizational)—which involve active participation of the student (Teboul, 1984, p191)—are affected by departmental policies and practices.

Section 3

Methods

Through in-depth intrinsic case studies (Stake, 1995), the existing data were collected from a total of 61 people (24 females, 37 males) through interviews at the two departments. Out of the 24 females, six were faculty and 18 were graduate students.

³ Pseudonyms were used to refer to the universities that participated and all participants in this study.

Of the 37 males, 20 were faculty and 17 students.⁴ Out of 61 participants, data from a sample of 14 were analyzed. Follow-up data were obtained from a sample of 11 faculty members who gave information on the implementation of policies and the professional socialization process and 14 female graduate students who provided information on how they experienced policies and the professional socialization process at the departmental level. Thus, a total of 25 people participated in the follow-up semi-structured interviews. The sample for the two sets of data comprised faculty members in leadership positions those that participated in teaching courses commonly taken by graduate students. The female graduate student sample composed of students from three graduate phases. Graduate students in mathematics participate in a sequence of three phases (these phases may overlap, but usually only slightly): coursework, preparation for comprehensive examinations, and dissertation completion. These three phases constitute considerable differences in the student learning process—participating in different communities of practice at each stage, then apprenticeship and mastery of the required skills (Lave & Wenger, 1991). To have a fuller understanding of the phenomena of this study, triangulation theory (Cohen & Manion, 1994) was applied to collect data from multiple sources of information—existing data and follow-up data from faculty and female graduate students from MU and SU. The study adopted Miles and Huberman's (1994) framework for qualitative data analysis, which comprises three main components: data reduction, data display and drawing and verifying conclusions. Further, individual cases were analyzed independently based on the four themes (Policies and practices, Anticipatory socialization, Organizational socialization, and Outcomes) and then cross-case analysis was done by comparing and contrasting the findings using Yin's (1994) theory of multiple case analyses.

Section 4

Results

The study found that departmental chairs, influenced by their personal beliefs and values, after identifying the problem and causes of the under-participation of female students in doctoral level mathematical sciences, not only made policy decisions to increase the number of women, but also participated in reaching out for talented potential female students (from high school, undergraduate and masters' levels) and engaged them in anticipatory socialization processes. After which some of them made decisions to apply for a PhD program in mathematics. The two math departments, separately established partnerships and collaborations with small liberal colleges where potential students were likely to come from and influenced the professors who encouraged their students to make decisions to pursue mathematics at the doctoral level. These professors further gave recommendations to their students, which played a significant role in their admissions. Applying a holistic model to admissions extended the increased participation of women in doctoral level mathematical sciences. By changing the traditional evaluation model of linearly ordering applicants to the use of a holistic model, which involved viewing the total picture of the applicant, more women were admitted on the basis of their potential to succeed at the graduate level. Among the efforts to make them succeed, was the restructuring of the existing policies, especially qualifying exams (without lowering the standards) and providing a supportive environment, not only to women students, but also to all graduate students.

Due to students' diverse backgrounds and levels of preparation for graduate mathematics study, faculty members provided bridge programs for the under-prepared students. For example, under-prepared students were advised to either take fewer courses or undergraduate courses; they were also allowed to retake qualifying examinations multiple times. Additionally, in both departments, new female graduate students were socialized into graduate life through mentorship from faculty and senior graduate students. New students were assigned faculty advisors to mentor them throughout their program. Faculty members facilitated the building of student communities which aided in the socialization of new students. Through these communities, graduate students gained membership in reliable support networks, and thus worked together to prevent fellow students from dropping out of school. Peers interacted with newcomers and showed them how to navigate the rites of passage (course taking, examinations, research) and how to survive the long-term process of becoming a professional. In that capacity, a senior student acted as a mentor and socializing agent. In the two departments, graduate students were given opportunities to participate as teaching assistants, graders, and mentors. As graduate students participated in those capacities, they underwent the process of socialization which enabled them acquire the requisite skills for their profession. This is a kind of apprenticeship in which newcomers to a community advance their skills and understanding through participation with others in culturally organized activities (Lave & Wenger, 1991; Rogoff, 1990).

⁴ Note that the focus for the existing data was on female students and students of color. Therefore the sample was comprised of both male and female students. However, the focus of this study is on female students. Therefore, data elicited from male students was excluded from the sample for this study.

In both programs, treating graduate students as junior colleagues and collaborator/partners in the graduate program was one way of removing obstacles and providing a supportive environment. Students' desire to persist was encouraged when they were treated as one of the faculty members (or rather as "faculty-in-waiting"), and when their opinions were respected by faculty. One department encouraged dual-hiring policy, which increased the number of women faculty, who, with other female speakers acted as role models to the incoming female students. Female students were motivated to see women mathematicians with families. This led to the critical mass of women students who persisted until the completion of their degrees.

Section 5

Discussion

The major policies and practices in the two departments associated with the increased female participation at the doctoral level mathematical sciences were initiated by individuals (departmental chairs). The role the two departmental leaders played in bringing change in their departments is compatible with Benowitz's (2001) description of transformational leaders: the source of their leadership skills was in their values and beliefs; they were visionary and change-oriented; they constantly sold their vision to others, and were committed and persistent; they sought the way forward; and they created trust and personal integrity. Consequently, through their transformational leadership skills, the two departmental chairs were able to initiate policies that brought changes in the recruiting and retaining of a critical mass of women. Likewise, the two departmental leaders acted as "policy entrepreneurs." According to Mintrom (2000, p152), "policy entrepreneurs can be identified by their efforts to introduce policy innovations to secure policy changes." Furthermore, policy entrepreneurs are willing to "invest their resources—time, energy, reputation, and sometimes money—in the hope of a future return; they advocate certain policy solutions to solve existing problems in pursuing personal interest, promoting their values, or affecting the shape of public policy" (Kingdon 2003, p122-123).

Previous studies defined the causes of the problem of the under-participation of women in mathematics from the learners' standpoint (Becker, 1990; Tinto, 1993; Parker, Rennie & Fraser, 1996; Henrion, 1997; Cooper, 2000). In contrast, the two mathematics departmental leaders at SU and MU defined the causes of the problem from the institutional standpoint: namely, faculty members who did not encourage undergraduate and Master's level female students to consider pursuing mathematics at the doctoral level; admission committees which used a traditional linear ordering of applicants model (based on GPAs and GREs) which acted as obstacles to the entry of some talented female applicants to doctoral level mathematical sciences. As a result, the two departmental leaders initiated policies and, with the support of their fellow faculty and institutional administration, implemented those policies to remove some of the obstacles deemed to hinder women from accessing mathematics doctoral programs. Faculty members' identification of talented women in the mathematics pipeline, and their subsequent encouragement to both major in mathematics and consider pursuing mathematics up to the doctoral level, enhances the increase of women in mathematics. For instance, faculty at the Department of Mathematics at MU identified undergraduates in their classes who might not have otherwise had the intention of proceeding after earning a Master's degree or even Bachelors degree, and encouraged them to apply to the doctoral program in mathematics.

Applying a holistic model to admissions increased the participation of women in doctoral level mathematical sciences. By changing the traditional evaluation model of linearly ordering applicants to the use of a holistic model, which involved viewing the total picture of the applicant, more women were admitted on the basis of their potential to succeed at the graduate level. This holistic approach is compatible with Senge's (1990) theory of having a fundamental shift of mind from seeing things as "parts" to seeing things as "wholes." Senge argues that everyone takes responsibility for the whole and that people need to move away from rule-boundedness towards a more holistic involvement or participation. Considering that the holistic model admitted students based on their potential to succeed, emphasis was put on programs (bridge programs) that would enable these students to participate in the socialization process as they learned to acquire professional knowledge.

The study found that some graduate students in the two mathematical sciences programs were under-prepared for graduate school. Some students underestimated the difficulty of the transition to graduate school. The requirements of graduate school created confusion and distress when the pressures of graduate work become evident. This supports Trowler's and Knight's (1999) complex theory of socialization processes, in which new graduate students must themselves negotiate the changes in order to be socially integrated. DeFour and Hirsch (1990) caution that failure to negotiate the change to graduate school reduces social integration in the department and the profession. Moreover, difficulties encountered during the transition can lead to withdrawal from graduate school (Egan, 1989).

However, the findings of this study in regard to the socialization experiences during the transition processes are compatible with Sullivan's (1991) argument that, in order to be integrated in the program and the profession, greater amounts of time should be devoted to both formal and informal activities within the department, producing a much tighter link between the social and academic aspect of students' lives. Although there are various levels of transition in graduate school (from undergraduate student to graduate, and then to graduate academic life; from student as course-taker to exam-taker to student researcher, and to dissertation writer; learning to teach and serving as a research assistant), this study focused on the transition from undergraduate or Master's programs to a doctoral program. Through the process of professional socialization, a newcomer is transformed from a lay person into a professional in a specified field, or from passive to active involvement, from spectator to active participation. A student who persists through the stages of transition will be better prepared for the profession he/she has chosen than one who drops out without completing the entire process of graduate socialization.

Although "advising" is not a synonym for "mentoring," its elements are incorporated into mentoring; thus this study uses "mentoring" to incorporate advising. Manzo (1994) argues that personal advising improves the retention of students in a doctoral program, especially when advisors use it as an opportunity to convey to students a strong sense that they want them to succeed. Manzo's (1994) argument corresponds with the philosophy of the Mathematics Department at MU: "We want you to be successful; we believe you can be successful, we will help you be successful." This philosophy played a significant role in guaranteeing the success of women. In both departments, new female graduate students were socialized into graduate life through mentorship from faculty and senior graduate students. New students were assigned faculty advisors to mentor them throughout their program. This finding builds on Cooper's (2000) argument that encouragement and moral support from mentors in graduate school plays an important role in student's decision to enroll and persist in graduate studies in mathematics. This study revealed that women persisted, in part, because of the encouragement they received from faculty members prior to joining the program and during the doctoral program.

Equally, bridge programs (taking fewer classes, taking undergraduate classes and summer programs that prepare students for qualifying examinations) helped new students adjust to the graduate academic life. Faculty members built academic and social programs to assist newcomers to adjust and learn to fit into the program. The findings of this study support the work of Olson, Downing, Heppner, and Pinkney (1986) on post-graduate students, in which it is suggested that mentoring-supervision programs clarify transitional issues for students and therefore enable them to be better prepared for the difficulties they are likely to encounter in their future professions. Faculty members facilitated the building of student-communities which aided in the socialization of new students. Through these communities, graduate students gained membership in reliable support networks, and thus worked together to prevent fellow students from dropping out of school. Peers interacted with newcomers and showed them how to navigate the rites of passage (course taking, examinations, research) and how to survive the long-term process of becoming a professional. In that capacity, a senior student acted as a mentor and socializing agent. This supports Tinto's (1993) "persistence theory" in which involvement with one's peers and with the faculty, both inside and outside the classroom, is itself positively related to the quality of student efforts, and in turn contributes to both learning and persistence.

Likewise, Schreiber (1989) reports that the formation of a peer group reduced student stress and supported students in coping with developmental and adaptive difficulties, including tasks inherent to their educational experience. According to Schreiber's findings, peer groups assisted students in those personal and social issues that affected their successful transition from lay person to professional. This implies that the informal aspect of learning generated in the peer group supports the academic objectives which are the manifest functions of a graduate student. For example, in the two departments, the student-community played a significant role in supporting female students during their transition into the program and as they persisted to the completion of their degrees. Although individual students reacted differently to the socialization process, the two departments each put substantial emphasis on preparing graduate students for the profession. Some female graduate students were trained in communication skills such as the presentation of research reports to the public. This enhanced their retention and graduation rates. This supports Herzig's (2004) argument that one path to a student becoming integrated is through particular forms of participation in communities of practice of graduate study. It is through participation in communities of practice that students learn to become professionals. In the two departments, graduate students are given opportunities to participate as teaching assistants, graders, and mentors. As graduate students participate in those capacities, they undergo the process of socialization which enables them acquire the requisite skills for their profession.

This is a kind of apprenticeship in which newcomers to a community advance their skills and understanding through participation with others in culturally organized activities (Lave & Wenger, 1991; Rogoff, 1990). These culturally organized activities are programs or mathematics classroom lessons that have been organized following specified policies that have been decided by departmental leaders with the support of faculty. In order for the newcomers to accomplish goals of advancing and specializing in certain skills (in this case mathematical skills that relate the group to others outside the group), they must play active specialized roles in these learning opportunities. Graduate students at the two departments participated in the designing of the curriculum, the selection of textbooks for courses that they will teach and, in general, in the formation of departmental communities. In each case, their opinions were listened to and taken seriously. This finding is compatible with Weidman, et al's (2001) model of the core socialization experience in the graduate degree program which argues that effective professional socialization depends on students' participation in departmental programs aimed at preparing them for a profession. By participating in departmental programs, graduate students develop a sense of identity: namely, that they feel they belong to the mathematics community as they prepare for their professions.

The findings of this study support Lave and Wenger (1991), Tinto (1993), and Herzig's (2004) arguments that students' participation, identity and sense of belonging in graduate school and in the mathematics community lead to retention in graduate school and in the mathematics profession; each of these features is an important outcome and contributor to the professional socialization process. Through professional socialization, graduate students developed a sense of community. Developing a sense of community can be conceptualized as a process of becoming a "full participant" in a community of practice (Lave & Wenger, 1991). Similarly, this study supports Brown's (1991) argument that one of the major goals of professional socialization is to facilitate the acquisition of a professional identity. Henrion (1997) adds that once the desire for mathematics is triggered, it needs to be reinforced by the mathematics community to create a sense of belonging in the student. I argue that insiders (professionals) have a responsibility to encourage and involve incoming professionals in the mathematics community in order to make them feel that they belong. The positive student-faculty interaction at the two departments helped students gain confidence both in themselves and in the faculty. Some of the student interviewees reported that professors were approachable and that they felt free to approach them whenever they needed. This indicates that there is quality interaction between students and faculty and the students took advantage of the opportunity to be mentored.

As a result, there was reported success of women in the professional socialization process—acquiring mathematical knowledge, and relevant skills required in the profession. This finding supports Girves and Wammerus' (1988) studies that students' interaction with faculty contributes to the professional socialization process. The quality of graduate students' relationships with faculty and the amount of mentoring opportunities each play a significant role in the success of women in mathematics (Herzig, 2004; Cooper, 2000; Smith & Davison, 1992; Hall & Allen, 1982). Faculty and students interviewed in the two departments indicated that in an attempt to overcome obstacles, both departments intentionally provided a positive supportive environment that made women feel valued and cultivated in them a sense of belonging. Treating graduate students as junior colleagues and collaborator/partners in the graduate program was one way of removing obstacles and providing a supportive environment. Students' desire to persist was encouraged when they were treated as one of the faculty members (or rather as "faculty-in-waiting"), and when their opinions were respected by faculty.

This supports studies, which argue that the treatment of students as "junior colleagues" enhances their professional identity and makes them more likely to stay enrolled in graduate programs to complete their degrees (Berge & Ferber, 1983; Girves & Wemmerus, 1988; Nerad & Cerny, 1993). Students begin to consider themselves as professionals when they feel regarded as professionals by those who have already achieved that status (Reader, 1957; Carroll & Tosi, 1977) Policies such as making the qualifying examination process more flexible for students, encouraged success in doctoral level mathematical sciences. Parker, Rennie and Fraser (1996) argue that the rigidity of the traditional program causes female students to be unable to complete their doctoral programs. Increased flexibility of policies, especially those concerning qualifying examinations and coursework, did not make it easier for women to pass through, nor did it dilute the quality of the academic standards. Although there were no specific policies and practices aimed at socializing women in the doctoral level mathematical sciences, in general, both departments were responsive to individual situations and tried to enable all students to be successful. Among the factors associated with the success of women in Mathematics at MU is the role of female faculty—the Mathematics Department at MU had six female faculty members, some with family, and SU had one.

Although this study supports the role model theory of Davies et al (1996) that the few role models, and the perception that access to career opportunities and salaries are limited, discourage women from enrolling in mathematics, the six female faculty members acted as role models to the incoming and enrolled students to persist in the program. Conversely, at SU, though there was only one female faculty member, the department succeeded in increasing the participation of females in the graduate program. At the same time this study raises questions about Davies et al.'s (1996) role model theory. Given that women students were successful at both MU (with six female faculty members) and SU (with one female faculty member) the situation is more complex than captured by Davies, Cinda-sue, and Ginorio et al. (1996). For example, students may have role models outside the department. I therefore conclude that while women faculty members may act as role models, there are also other role models outside the departments and other noteworthy factors (for example departmental policies and practices, the providing of a supportive environment and professional socialization) that play a critical role in the success of women in doctoral level mathematical sciences.

Section 6

Conclusion

This study revealed that there is an “existing pool” of talented women in the mathematics pipeline (K-12, Undergraduate and Master’s level), yet there exists low participation of women in mathematics, especially at the doctoral level. This means that there is some disconnect between women in K-12, those who get their Bachelors and Master’s degrees in mathematics and the decision to pursue mathematics at the doctoral level. Mathematics departments can avert this situation by initiating policies aimed at reaching out and encouraging women to consider majoring in mathematics and pursuing mathematics up to the doctoral level. If graduate mathematics departments are to increase recruitment and persistence of women students, changes to the existing traditional policies are necessary; changes in recruitment, admission, retention, evaluation and hiring of faculty policies. Departments should consider dual-hiring in order to have female faculty act as role models to the incoming female students. Similarly, the processes of mentoring and socializing of female graduate students are critical in ensuring their access to doctoral programs, their retention of information in the programs and, ultimately, the completion of their doctoral degrees. Consequently, if departmental leaders and faculty, through a shared and cooperative effort, provide female graduate students with comprehensive, high quality academic and educational support services, programs, and opportunities, women are more likely to persist in doctoral mathematics studies.

Note: This paper is based on the research study conducted in two university mathematics departments, in the U.S.

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