Women with Advanced Degrees in Mathematics in Doctoral Programs in Mathematics Education

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Abstract: I report on the results of my dissertation work, a qualitative investigation on the nature of the graduate school related experiences of women in collegiate mathematics education doctoral programs. I interviewed 9 women at 3 universities. Each woman had an advanced degree in mathematics and chose to move into a collegiate mathematics education doctoral program housed in a mathematics department. I used narrative and autoethnographic approaches, and consequently I was a co-participant. The focus of the two-interview protocol was exploring and extending the framework for doctoral mathematics student experience suggested by Herzig (2004a, 2004b). Results support the existing framework offered in the literature, as well as the emergence of 3 new categories: self as scholar, "my teaching," and future possible self.

Each year more than 2000 students enter Ph.D. programs in mathematics in the United States. About 1000 finish their degrees, or rather, the completion rate for graduate students in mathematics is around 50%. Among the 50% who leave, about 10% move to an allied field (Council of Graduate Schools, 2008). Of the more than 1000 doctoral graduates each year in mathematics, about 30% are women (AMS, 2006). Similarly, at the end of their first year after graduate school among the nearly 60% of graduates who have taken academic positions (full or part-time), about 30% are women (extrapolated from Kirkman, Maxwell, & Rose, 2005, 2006, 2007).

However, in collegiate mathematics education the picture is quite different. On average each year fewer than 100 individuals graduate with doctorates in mathematics education (with about 10 of those being in collegiate mathematics education). While 30% of mathematics

doctorates are women, approximately 65% of Ph.D.s in mathematics education go to women (Reys, 2000; Reys, 2003). In 2005 over 40% of positions available for mathematics education doctorates were left unfilled, whereas positions available for mathematics doctorates were inundated with applicants—leaving few, if any, positions unfilled and many Ph.D.s in mathematics un- or under-employed (AMS, 2006). That is, each year there is a higher demand for doctorates in mathematics education than there are qualified individuals to occupy these positions (Reys, 2006). On the other hand, each year there are far more mathematics doctorates than there are academic positions (extrapolated from Kirkman, Maxwell, & Rose, 2006, 2007).

More than 80% of people who complete mathematics doctorates eventually take jobs where teaching is their primary responsibility (Chen & Zimbler, 2002). These Ph.D.s in mathematics become mathematics instructors and professors who prepare the next generation of K-12 mathematics teachers, mathematics educators, and research mathematicians (Reys, 2002). This indicates that more than half of graduates with the Ph.D. in mathematics end up with jobs that require them to build expertise in mathematics education. Moreover, the expectation that a new Ph.D. mathematician will have such expertise is reflected in the growth of organizations and programs to help research mathematics doctoral graduates learn about teaching (e.g., Project NeXT, Preparing Future Faculty, and post-doctoral positions funded by the National Science Foundation VIGRE program; see, for example, Holton, 2001).

The program someone might follow to become a college mathematics professor by way of a Ph.D. in mathematics and the program someone might follow by way of a Ph.D. in collegiate mathematics education is largely the same through at least the bachelor's degree and much of the master's degree. Most collegiate mathematics education doctoral programs require graduate students to complete doctoral-level mathematics courses and doctoral-level

comprehensive or qualifying exams. Based on my research into the requirements for doctoral programs in collegiate mathematics education, using information obtained through links to university's descriptions of their programs maintained by the Mathematical Association of America's Special Interest Group on Research in Undergraduate Mathematics Education website (Hauk, 2004), the significant difference between doctoral collegiate mathematics education programs and doctoral mathematics programs often occurs *after* comprehensive or qualifying exams. In some collegiate mathematics education programs, such as those at Arizona State University and Central Michigan University, the difference between doctoral mathematics and collegiate mathematics education programs may only be the topic of the dissertation. In others, such as Portland State University, the University of Northern Colorado, and Western Michigan University, the trajectory diverges within the first two to three years of doctoral study, where mathematics education students take courses and comprehensive or qualifying exams in research design and educational theory in addition to mathematics exams.

Also, it is the norm for mathematics doctoral students, regardless of the specialized field of their dissertation, to take an array of graduate courses in mathematics (e.g., analysis, topology, algebra) in order to pass written comprehensive or qualifying exams. Later, if these individuals take academic positions where they are expected to teach undergraduate courses in fields outside their area of expertise (e.g., an analyst teaching algebra or a topologist teaching analysis), they will have their own undergraduate and graduate classroom experiences in those outside areas and connections between their specialization and these outside areas to aid in their preparation and teaching of the courses. On the other hand, those who complete doctorates in collegiate mathematics education in mathematics departments and become college professors may be called upon to teach advanced undergraduate mathematics courses (e.g., a collegiate mathematics

education researcher teaching undergraduate algebra or topology). In general, these individuals will have taken doctoral-level mathematics courses similar to those that the mathematicians did. However, the connections these specialists will bring to the outside area will be in their expertise on teaching, pedagogy, and how college students learn.

Question Guiding the Research

The goal of my research was to begin to build a body of research about the nature of graduate student experiences in doctoral mathematics education. Specifically, this research project aimed to address the problem that there is an imbalance between the preparation of people coming out of research universities as mathematics academicians and what universities and colleges in the U.S. need in terms of mathematics faculty. One of the ways to investigate this is by considering the different routes to "college math professor" and examining the kinds of experiences people have along each of these routes. Herzig (2002, 2004a, 2004b), Hollenshead, Younce, and Wenzel (1994), Stage and Maple (1996), and others have investigated the route of *mathematics* Ph.D. My research focuses on the route of *collegiate mathematics education* Ph.D. In particular, I focused on the experiences of women because about 65% of graduate students in doctoral programs in mathematics education are women (Reys, 2003). The research question guiding my dissertation research was: What is the nature of the graduate school related experiences of women who leave advanced mathematics programs to pursue the Ph.D. in collegiate mathematics education in a mathematics department?

Situating the Research

This is a project that is very personally close to me, as it grew out of a series of experiences I have come to call "intentional stumbling." Ellis (2004) made a statement in her book that stayed with me throughout this research project:

> I tend to write about experiences that knock me for a loop and challenge the construction of meaning I have put together for myself. I write when my world falls apart or the meaning I have constructed is in danger of doing so. (p. 33)

The results of my research included discussion of the educational experiences that have knocked the participants and me "for a loop." For me, this included making the move from advanced mathematics to a doctoral program in collegiate mathematics education and negotiating what that meant for me in terms of the future self I had previously envisioned.

My research employs two methodological approaches that are not commonly used in mathematics education research, autoethnography and narrative inquiry. This project began as a very personal investigation of my experiences in graduate school. From that personal endeavor, it grew into an investigation into the experiences of other women who made similar moves from mathematics to collegiate mathematics education. I chose a narrative inquiry because it was a good partner to autoethnography in that it offered a way to expand the investigation of experience as story into talking with other women about their experiences using similar techniques.

As humans, our lives are shaped by the stories woven through our experiences. We make sense of our world and our lives through our stories (Ellis, 2004). These are stories of who we are, who we are interpreted to be by others, how we interpret others, and how these stories evolve as we grow and change throughout our lives. Narrative inquiry, then, is presenting—as a story—the study of experience, in which the researcher inquires "inward and outward, backward and forward," into the past, present, and future of experience (Clandinin & Connelly, 2000, p. 50). A particular narrative approach, *autoethnography*, is founded on the theory that humans as researchers are not separate from that which we study. Moreover, many autoethnographers assert

that we cannot study something personally relevant without being fully steeped in every aspect of the research process (Ellis, 2004; Ellis & Bochner, 2000).

Theoretical Framework

Clandinin and Connelly propose a strategy for inquiry that embraces the idea of experiential continuity by identifying a three-dimensional research framework placing *temporality* (past, present, and future), *sociality* (social and personal), and *place* (situation) on each of the three axes. More than providing concrete "thick, rich descriptions" about a particular situation or setting, I also consider temporality—the historical implications associated with the current behaviors, actions, and words and their anticipated or possible projection(s) into the future (Connelly & Clandinin, 2006). This three-dimensional framework served as a structure for considering and analyzing the narrative data.

In particular, I used these three dimensions of experience to refine a theoretical framework about doctoral student experience. I began with seven aspects of mathematics graduate student experience identified in the literature of Herzig (2002, 2004a, 2004b), Hollenshead, Younce, and Wenzel (1994), Stage and Maple (1996), and Tinto (1993): (1) community, (2) visibility and guidance, (3) moral support and encouragement, (4) mentoring and role models, (5) teaching quality, (6) balancing being a graduate student with other life roles, and (7) intellectual ability.

The first aspect of experience, *community*, referred to the graduate students' feelings of membership with the faculty members and fellow graduate students within a department. This included discussion of the department's academic and social communities. *Visibility and guidance* referred to the degree to which students felt they were noticed or acknowledged by the faculty in their respective departments. That is, graduate students reported on in the research

literature felt "visible" when mathematics faculty members took note of their research interests, began to assist them in identifying a professional path, spoke with them about preparing to travel along that path, and offered to help them learn how to acquire the tools necessary to succeed along the way. *Moral support and encouragement* meant support and encouragement offered by others (e.g., faculty, fellow graduate students, family members, etc.). Descriptions of such feedback ranged from encouragement or discouragement to pursue education in mathematics to being key factors influencing persistence in a mathematics doctoral program. *Mentoring and role models* described influential people in the graduate students' educational experiences who served as a mentor or professional model. These influential individuals included professors, advisors, and important mathematicians. *Teaching quality* referred to graduate students' perceptions as students of the teaching they were offered in their courses. *Balancing roles* referred to the conflict or tension between the profession of mathematics and other roles such as parenting, relationships with significant others, and membership in other communities. *Intellectual ability* appeared in much of the literature but was not well-defined. It might pertain to a graduate student's perception of their own intellectual ability or the perceptions someone else has about their intellectual ability. This would include things that a faculty member might say to another faculty member about the intellectual capacities of a graduate student.

Methods

This study took place in the mathematics departments of three doctoral granting universities in the United States, State Teachers College (STC, a doctoral intensive university in the western United States), Urban State University (USU, a doctoral intensive university in the western United States), and Suburban State University (SSU, a doctoral intensive university in the midwestern United States). The collegiate mathematics education Ph.D. programs at all three

institutions were advertised as combining advanced mathematics preparation with advanced work in education and a dissertation in mathematics education research. They were aimed at attracting students who already had master's degrees in mathematics and a strong interest in collegiate mathematics education.

I conducted two detailed interviews with each of 8 women, Eve Bronson, Sue Foster, Maureen Isaac, Crystal Joad, Lena Kraig, Nell Ogden, Dale Upton, and Greer Wallace (all pseudonyms). Also, because of the autoethnographic nature of this research, I was a ninth participant. Each woman had begun advanced degree programs in mathematics and completed a master's degree in mathematics or a master's degree in mathematics education with at least 80% of coursework completed in advanced mathematics. All were either currently working on the Ph.D. in collegiate mathematics education in a mathematics department or, in the case of Maureen Isaac, had recently (within one year) completed such a degree.

Each interview ranged from 45 to 90 minutes in length and was audio or video recorded. The first interview focused on the pre-doctoral mathematics education program experiences of each woman. The second interview was about her experiences in doctoral program(s) in mathematics departments (e.g., some women began Ph.D. mathematics work before deciding to switch to the Ph.D. in mathematics education). Specifically, I probed for information in and outside the contexts of the seven aspects already identified in the literature, encouraging participants to discuss the ways in which these characteristics (1) affected their experiences in mathematics and in mathematics education, (2) did not affect those experiences, or (3) may not characterize their experiences—thus allowing space for new characterizations of their experiences to emerge. A conversational approach to the interviews honored the uniqueness of the responses of each participant. It allowed a level of flexibility in each interview for new

information to emerge. Also, for consistency in my autoethnographic investigation, I was interviewed using the two interview protocols.

Additionally, I kept two detailed journals—one as a co-participant and one as a researcher. In the first, I reflected on my own graduate experiences in mathematics graduate programs and in a collegiate mathematics education Ph.D. program. I began by writing about and reflecting on my own responses to the interview questions. As I continued to write during data collection and analysis, I noted other relevant topics that emerged for me as a co-participant. I wrote about my experiences with each new topic, making note of other new relevant topics that emerged, and so on. The second journal focused on my reflections as the researcher and about the research process. After each interview I wrote an interpretive summary of the interview, in which I took stock of what was discussed during the interview and noted my preliminary thoughts on what we talked about. This assisted in my preparation for participant debriefing sessions, follow-up interviews, and later reporting. Each of these journal entries also addressed questions about the strength and effectiveness of the interview.

My inductive hypothesis for data analysis was that the 7 aspects of caring are necessary and sufficient to describe the doctoral experience for graduate women in collegiate mathematics education. This emerged from pilot study work, which suggested there were other categories of experience that were unexplored. I used constant-comparative methods to identify evidence of the seven aspects of experience outlined in the literature, as well as other themes that emerged (i.e., descriptions of experiences that did not fall into one or more of the seven existing categories). As part of this I offer details on the five-stage writing process (extrapolated from Clandinin & Connelly, 2000, pp. 130-135) that made up the first three steps of the four-step analytic induction process (extrapolated from Patton, 2002; see Table 1 below).

Table 1. *4-Step Analytic Induction and 5-Step Writing Cycle*

<table>
<tr><td>Step 1</td><td colspan="2">Separate interpretive summaries developed into narrative cases for each participant.</td></tr>
<tr><td rowspan="3">Step 2</td><td colspan="2">Open and axial coding for pattern matching with the existing theory, new theme identification, and the identification of centers around which ideas are connected.</td></tr>
<tr><td>Passes 1-4</td><td>Pass 5</td></tr>
<tr><td>Narrative coding for dates, places, names, events, actions, and topics, as well as sorting for temporal, social, and physical discussions.</td><td>Develop interim texts.</td></tr>
<tr><td>Step 3</td><td colspan="2">Conjecture a revised theory.</td></tr>
<tr><td>Step 4</td><td colspan="2">Falsification of conjectured theory.</td></tr>
</table>

Results

The primary results of this research appear on three levels. First, I found the seven categories of experience to be across the experiences of the 9 women, thus establishing a connection with women in collegiate mathematics education doctoral programs in mathematics departments to graduate students in doctoral mathematics programs. Second, I expanded upon the literature with the identification of three new categories, “my teaching”, self as scholar, and future possible self that appeared across the experiences of the 9 women. Third, I refined the seven aspects from the literature and gave detail about the three new characteristics by identifying and specifying the meanings of each category, as well as investigating and illustrating the nature of the experiences that fell into each.

The first new category identified, *“my teaching”*, is about their own teaching. All of the participants talked about themselves in the classroom teaching mathematics and many talked about its significance in their decisions to move to collegiate mathematics education. This

differed from teaching quality, which related to a critique of the quality of teaching offered by others. The second, s*elf as scholar* was a new category that emerged as I noticed the women reflecting on their experiences as learners in the classroom and as researchers connecting their research activities to experiences in the classroom (both as learners and as instructors). The women who were further along in their respective programs and no longer taking classes (Crystal Joad, Lena Kraig, Maureen Isaac, and I) talked more about our experiences as researchers and not as much about our experiences in classes as learners. That is, self as scholar is about growth, over time, from viewing oneself as a student in the classroom to a researcher. The third new category, *future possible self*, was a meta-category that seemed to be lying across the others. In talking about their past and present experiences, the women often mentioned how those experiences projected into the future and affected different aspects of their lives (both in and out of graduate school).

The third layer of results is a refinement of the categories. I spent time defining and refining each of the 10 categories as reported by the women in their interviews. Specifically, I paid careful attention to how the aspects were linked to and nested within each other.

Rather than going into detail about the specifics of the results across all 9 women, I offer instead an excerpt from *The Accidental Graduate Student,* a fictional vignette I created to represent the experiences of Eve Bronson. It offers an in-depth look at the ways in which one woman talked about her experiences in graduate school. Also, it is representative of multiple facets of my research. Using a narrative approach to the reporting, I was able to present Eve's recounting of her experiences in a mathematics education doctoral program in her own words. I have also folded autoethnographic elements into the story. I wrote myself into this as a result of the emotional response I had to Eve's story. I wanted to incorporate my own authentic responses

based on the ways in which I related to her story. In addition to embodying the reporting techniques, it is also representative of the three levels of the results. In this excerpt, Eve readily speaks in the language of many of the 10 identified categories. Specifically, this narrative highlights community, visibility and guidance, moral support and encouragement, mentoring and role models, balancing roles, self as scholar, and future possible self. Her story also demonstrates the interconnectedness of these different aspects of experience. For example, in talking about having a community of peers within the department, she ties in the resulting visibility she feels, the support and encouragement she has received, and the mentor she has found.

This fictional story is set in a mathematics oral history seminar, where the participants have taken turns sharing their respective mathematical histories. Today is Eve's turn. Eve feels she has stumbled along her path to a doctoral program, with opportunities arising "accidentally" along the way, always at the "right time." We join the seminar as Eve is completing her discussion of her master's degree and is beginning to talk about her experiences as a Ph.D. student in collegiate mathematics education in a mathematics department. Although this conversation never took place as it is presented here, I feel it maintains the integrity of the experiences of all three women.

Excerpt from: The Accidental Graduate Student

"So I knew during my second year I was done," Eve continued. "And then my friend Robert talked to me and he said, 'Look there is this school up north. They do math just like we do *and* they do math education. You should go check it out.' He told me to be aware that other people in the community of mathematics will think that I have stepped down. And so because of that I was like, 'Ha! I hung in this program this long. If I take a step backwards it will be easy.' I didn't know what math ed. was."

"I didn't know what math ed. was, either," Allison added. "*I* thought it was a teaching degree for failed mathematicians."

"Yeah, when I first got here I had no idea what it was about," Eve said. "And then, just talking with my peers, I heard that K-12 was going to have to be my main focus, and I panicked. I'm not interested in that. Then I found out that, as a math ed. person, my responsibilities in a math department would not be geared towards teaching upper level mathematics. So I panicked about that. I didn't know where I fit. And then last year, moving here, to a new school and a new graduate program in math ed. was quite traumatizing for me. I came to school. I showed up every day, and I did the things I had to do to be a student and a teacher. But I really, um, wasn't here, um, mentally and emotionally. I had other things on my mind—trying to provide for my family outside of here was a lot more stressful than I thought."

Eve's face began to darken to red and tears welled in her eyes. Crystal stood to retrieve the box of tissues on the table by the door. She handed the box to Eve, who wiped her tears.

"And then I got bombarded with the reading and writing," Eve said, sniffling. "I mean, I enjoy reading and writing. I actually read for pleasure. But it was just hard. And I wasn't getting answers from anybody. I would go for help. I'm not the student to wait until the 14th week saying, 'I really need a B.' I went every day and nobody was helping me. I was thinking, 'What am I going to do? *There are no jobs here*, and I *so* want my Ph.D.' I kept coming here every day because that was an obligation I said I would do. I did what I had to do, but I really can't say my heart was in it. It wasn't enjoyable. I knew I was gonna leave or get thrown out."

"But you're here now." Crystal said, reaching over and taking Eve's hand in hers.

"It's through the peers here. They helped me realize I wasn't alone," Eve said, wiping her tears with her free hand. "My peers made sure I contacted Dr. Smith. 'She's got a big heart,' they

said. ‘Give her a chance.’ So, I went and talked to her about working under her. And her response crushed me. She said, ‘I’m not sure you’re dedicated to this program 100 percent.’ And I didn’t know Dr. Smith other than as a course captain, and she scared the shit out of me on some level. So I emailed her back, and it was not nice. No, it’s not that it wasn’t nice. It was just very powerful. I knew that in that email I was fighting—literally for my life as a math educator. I said, ‘Look, I’ve had a rough year, but I can do this. I’m not a dumb ass. I need—I deserve to be here!’ And I think that’s what she was looking for.

“Damn, she’s good for that!” Allison said, wiping her own tears from her eyes.

“So that was a high point. First, somebody believed in me. And second, I had an advisor. And from what I knew of Dr. Smith, she is a very brilliant woman and I wanted to learn from her. And that’s what I needed – somebody with that clout to say, ‘I believe in you.’ I mean I needed someone to stand up in front of this department. And to me, that’s what that was. Her accepting me as her advisee was letting everybody know, ‘I believe in her.’

“It sounds like you believe in you a little more these days,” Crystal said.

“I do. I’m feeling really good. I’m just going into my second year and I have a pilot study underway. I’ve got a research proposal underway, and I’ve got an advisor that backs *me* a hundred percent. I’ve got funding. I’ve got a place in the department. Last year, there was doubt-about lots of things. Not just school. So um, um now I’ve got, um, a fabulous advisor. And amazing peers. Give me another tissue!”

“Me too.”

“Me too!”

The three women laughed as they pull tissues from the near-empty box, wiped tears, and blew their noses.

"I mean, this is a research group. We're doing this math history project. But we're more than that to me. It's a support group. We don't compete. We're not competing against each other. We get together once a week. We hold hands, cry, laugh. 'What can I do for you?' There's no way I can fail with that kind of support. And considering the level of emotion I had to deal with last year, I'm just so excited to kind of land on my feet a few steps ahead of the game.

"It sounds like you've really come a long way in a year," Crystal said.

"I really have," Eve replied. "I feel like I am fully participating in the community of the department. I've got friends that support me mathematically and spiritually and emotionally. So I'm set. I'm definitely in a unique position."

Conclusions and Implications

The results of my research indicate that the initial 7 categories describing mathematics doctoral graduate students' experience are necessary to characterize the graduate experience for women in collegiate mathematics education Ph.D. programs, but are not sufficient. In particular, the three new categories of "my teaching", self as scholar, and future possible self emerged. My research also departed from previous similar work in that my use of conversation-based narrative and autoethnographic techniques allowed for an investigation of the experiences of graduate women *from their perspective*—in the ways they expressed it. My approach expanded upon the existing literature for doctoral mathematics students in that I reconstructed it in the context of doctoral collegiate mathematics education. Part of that reconstruction included an interview protocol to explore how participants' experience might be different from the norms established in the literature for doctoral mathematics graduate students.

Results of this research present multiple threads for future investigation and application. First, interviews with more graduate students, including men in collegiate mathematics education

programs will facilitate deeper, richer descriptions of the categories and shed further light on the ways in which they are distinct categories, as well as linked to one another. For example, this might also include the development of an interview protocol directed at asking questions about graduate students teaching and learning related experiences in graduate school. I could also take this new framework back to doctoral mathematics programs and interview graduatre students there to investigate the conjectures I've made in this research, as well as continue to refine the literature on graduate student persistence and attrition in doctoral mathematics programs.

Additionally, mathematics departments may want to consider some things as a result of this research. As was reported in the experiences of the 9 women participating in this project, recruiting and maintaining retention in collegiate mathematics education are related to the key features of community, visibility and guidance, moral support and encouragement, mentoring and role models, teaching quality, balancing roles, intellectual ability, self as scholar, "my teaching", and future possible selves. These are important to mathematics departments interested in developing Ph.D. programs in collegiate mathematics education as they need to know the kinds of cultural conflicts they may be undertaking within the departments.

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