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Alternate Trajectories: Women Moving into Mathematics Education

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Abstract

While only about one-third of each year's doctoral graduates in mathematics are women, about two-thirds of the doctoral graduates in mathematics education are women. This article reports on the results of a qualitative investigation into the nature of the graduate school-related experiences of women in collegiate mathematics education doctoral programs (Toney, 2008). Eight women with advanced mathematics degrees were interviewed. Each woman chose to move into a collegiate mathematics education doctoral program in a mathematics department. The two-interview protocol explored and extended a framework about women doctoral mathematics students' experiences suggested by the research of Herzig (2002, 2004a, 2004b), Hollenshead, Younce, and Wenzel (1994), and Stage and Maple (1996). Results support an addition of three new categories to this framework: self as scholar, "my teaching," and future possible self. Concluding remarks include suggestions for future research and new directions for practice, graduate program development, and faculty recruitment.

Introduction

Each year more than 2000 students enter Ph.D. programs in mathematics in the United States. Only half will finish their degrees, and only about 30% of these graduates are women (AMS, 2011). Similarly, women comprise only about 30% of the approximately 600 mathematics graduates who take academic positions (full- or part-time) in the first year after graduation (extrapolated from Cleary, Maxwell, and Rose, 2010, 2011, 2012, 2013). On the other hand, the picture in collegiate mathematics education is quite dif-

ferent. On average, while fewer than 100 individuals graduate with doctorates in mathematics education annually, with about 10 of those in collegiate mathematics education, about 65% of these graduates are women (Reys, 2003, 2008).

In 2012 over 30% of positions available for mathematics education doctorates were left unfilled, while 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 (Cleary, Maxwell, & Rose, 2013; Reys, Reys, & Estapa, 2013). As a result, each year there is a higher demand for doctorates in mathematics education than there are qualified individuals to occupy these positions (Reys, 2006, 2008; Reys et al., 2007; Reys, Reys, & Estapa, 2013), and proportionally many more of these candidates are women.

In spite of these differences, 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 K-12 mathematics teachers, mathematics educators, and research mathematicians, indicating 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 (Reys, 2002). Moreover, the program someone might follow to become a college mathematics professor by way of a Ph.D. in mathematics versus a Ph.D. in collegiate mathematics education is largely the same through the bachelor's degree, and often the master's degree. Additionally, most collegiate mathematics education doctoral programs require graduate students to complete doctoral-level mathematics courses and doctoral-level comprehensive or qualifying exams in mathematics (extrapolated from Hsu, 2013).

The goal of this study was to initiate a body of research about the nature of graduate students' experiences in doctoral mathematics education. One of the ways to investigate this is to consider the different routes to 'college math professor' and examine the kinds of experiences people have along each of these routes. Others have investigated the route of the *mathematics* Ph.D. Within this body of research, much attention has been given to the underrepresented population of women in mathematics (e.g., Herzig, 2004a, 2004b; Hollenshead, Young, & Wenzel, 1994; Stage & Maple, 1996). The research presented in this paper considers the route of the *collegiate mathematics education* Ph.D. Not only does this population of students have extensive mathematics backgrounds, but they also chose to move into doctoral programs housed in mathematics departments, thus placing them in the position of having a rich understanding of the culture of mathematics and of the culture of mathematics education. That is, this research is about the explicit and implicit reasons behind that choice, as well as the social consequences of that choice. In particular, the focus here is on the experiences of women because of their higher

proportionality in the mathematics education field (Reys, 2003).

The question guiding the research was: *What is the nature of the graduate school-related experiences of women who move from advanced mathematics programs to pursue the Ph.D. in collegiate mathematics education in a mathematics department?*

Theoretical Framework

Clandinin and Connelly (2000) 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. That is, in addition to the usual "thick, rich descriptions" about a particular situation or setting, also considered and addressed are the historical implications associated with participants' current behaviors, actions, and words and their anticipated or possible projection(s) into the future. In particular, the research used these three dimensions of experience to refine a theoretical framework about doctoral student experience among women in mathematics. The study began with seven aspects experience identified across the research of Herzig (2002, 2004a, 2004b), Hollenshead, Younce, and Wenzel (1994), and Stage and Maple (1996), all of whom focused on the experiences of women in doctoral mathematics programs: community, visibility and guidance, moral support and encouragement, mentoring and role models, teaching quality, balancing graduate student roles with other life roles, and intellectual ability. This seven-part framework is the frame upon which women's experiences within mathematics education were explored.

Community referred to the women's feelings of membership with the faculty members and fellow graduate students within a department. Integration into the community of a department is essential for persistence in the field of mathematics (Herzig, 2002, 2004a, 2004b; Hollenshead, Younce, & Wenzel,1994; Stage & Maple, 1996). This includes a sense of community among mathematics graduate students and a perception for graduate students about their membership in the community of mathematicians.

Visibility and guidance referred to the degree to which the women felt they were noticed or acknowledged in their respective departments (Herzig, 2002, 2004b; Stage & Maple, 1996). That is, they 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.

Ranging from encouragement or discouragement to pursue education in mathematics to being key factors influencing persistence in a mathematics

doctoral program, *moral support and encouragement* meant support and encouragement offered by others (e.g., faculty, fellow graduate students, family members, etc.; Herzig, 2004a; Stage & Maple, 1996). Herzig (2004a) found that women were more aware of receiving support and encouragement, and more aware of its absence, than their male counterparts. She also noted women were less likely to begin and persist in graduate mathematics programs when avenues of support and encouragement were not seen as accessible or available to them.

Mentoring and role models described influential people, including professors, advisors, and important mathematicians, in the women's educational experiences who served as a mentor or professional model (Herzig, 2004b; Hollenshead, Younce, & Wenzel, 1994; Stage & Maple, 1996). Specifically, participants in Herzig's (2004b) work reported looking up to their professors and wanting to know more about what they thought about mathematics, how they approached creating new mathematics, and how specific problems professors worked on fit into the broad scope of mathematics. Upon entering graduate school they expected to get this from their professors − to be treated as 'junior colleagues' (Herzig, 2002, 2004b).

In the research of Herzig (2002, 2004a, 2004b) and Hollenshead, Younce, and Wenzel (1994), discussion of *teaching quality* was based on women's perceptions about how their opportunities to learn mathematics were facilitated by the efforts of their professors. Reports of graduate students' observations about teaching quality most often were comments on poor teaching rather than good teaching. Common concerns among participants about poor teaching quality included comments about lecture quality, course feedback, and the method of information delivery.

Balancing roles described the conflict or tension between the profession of mathematics and other roles such as parenting, relationships with significant others, and membership in other communities (Herzig 2002, 2004a; Stage and Maple 1996). Herzig (2002) reported women feeling faculty 'expected them to be single-mindedly devoted to mathematics' (p. 186). Most indicated difficulties and guilt at balancing a life outside of the demands of the doctoral program and spoke of the difficulty of choosing between focusing solely on mathematics and finishing quickly, or paying attention to other communities to which they belonged. Participants with Stage and Maple (1996) commented on the 'isolation' of the subject of mathematics from 'other areas of interest and from the realities of everyday life' (p. 38).

Intellectual ability appeared in much of the literature but was not well-defined. In some research, the phrase refers to the perceived intellectual ability of a graduate student by another (i.e., how capable faculty members or other graduate students perceive someone to be; Herzig, 2002). In other research, it is about mathematical literacy in the broadest sense (e.g., being able to anticipate how to speak and behave in mathematically loaded situa-

tions so as to appear knowledgeable; Herzig, 2004a, 2004b; Stage & Maple, 1996). Common across the literature, intellectual ability is the only category where authors report on participants' self-judgments.

Methods

The study consisted of interviews with eight women in collegiate mathematics education programs house within the mathematics departments of three doctoral granting universities in the United States. Aimed at attracting students who already had master's degrees in mathematics and a strong interest in college mathematics education, the collegiate mathematics education Ph.D. programs of these three institutions were advertised as combining advanced mathematics preparation with advanced work in education and a dissertation in mathematics education research.

Of the 126 institutions that offer doctoral study in mathematics education (Reys et al., 2001), there were only 10 collegiate mathematics education Ph.D. programs in the United States housed in mathematics departments at the time of the study (Hsu, 2013). Therefore, the three participating mathematics departments were relatively unusual within the broader scope of both mathematics education and mathematics in that each offer a Ph.D. in collegiate mathematics education. That is, a graduate student in the department could write a dissertation whose topic was mathematics education research rather than mathematics research. All three programs required comprehensive and oral exams in mathematics and mathematics education. Two of the departments also offered the Ph.D. in mathematics. Graduates of all three programs have gone on to be college professors (in mathematics departments and schools of education), teacher-leaders in elementary and secondary schools, K-12 school district consultants, and professional researchers and policy-makers in mathematics education.

Specifically, the study involved two detailed interviews with each of the eight women, Crystal, Dale, Eve, Greer, Lena, Maureen, Nell, and Sue (all pseudonyms). Each 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, had completed such a degree the previous year. Crystal and Lena were working on their dissertation research. Greer had taken her comprehensive exams, not passed, and was preparing to leave her program. Dale, Nell, and Sue were in the process of taking their comprehensive exams. Eve was in her second year of doctoral study, pre-exams.

The first interview focused on the women's pre-doctoral mathematics

education program experiences; the second was about their experiences in doctoral program(s) in mathematics departments. An interview guide outlining the topics to be covered in each interview drew from preliminary results that emerged from pilot work (see also Toney, 2008). Findings from the pilot study emphasized the need to highlight self-reflective aspects of graduate student experience not reported in the literature. Therefore, prompts focused on the social, physical, and temporal spaces of women moving from advanced degree programs in mathematics to advanced degree programs in collegiate mathematics education. A conversational approach that avoided the explicit language of the initial seven aspects of experience probed for information in and outside these contexts. This encouraged participants to discuss the ways in which these characteristics either affected their experiences in mathematics and in mathematics education, did not affect those experiences, or may not characterize their experiences − thus honoring the uniqueness of the responses of each participant and also allowing flexibility for new characterizations to emerge.

The inductive hypothesis for data analysis was that the seven aspects of experience are necessary and sufficient to describe the doctoral experience for graduate women in collegiate mathematics education. Constant-comparative methods were used to identify evidence of the seven aspects of experience, as well as other descriptions of experiences that did not fall into one or more of the seven existing categories. An additional component of analysis incorporated aspects of the five-stage writing process suggested as part of a narrative inquiry by Clandinin and Connelly (2000). That is, as part of verification and falsification coding for matching with the existing theory, analysis included additional coding for dates, places, names events, actions, and topics, as well as sorting for temporal, social, and physical discussions (Clandinin and Connelly, 2000; Patton, 2002).

Results

The primary results of this research appear on two levels. First, the seven categories of experience were consistent with the experiences of the eight women. Second, findings required an expansion of the literature with the identification of three new, primarily self-reflective categories − "my teaching," self as scholar, and future possible self − that appeared across the experiences of the eight women.

Community

All eight women spoke of the communities they had established in their Ph.D. programs. In particular, Sue highlighted her experience within the community:

> Well, here there's a community, and that community is built upon in a lot of different ways. Just having that space out there − you will just sit down at a table with people you are taking a class with and start working on problems together. So the physical space kind of encourages that, and the teachers encourage that. There are a lot of seminars, not just in math ed., but in a lot of different topics. So, there are a lot of ways to get involved in the community.

The women also talked about how the personal and intellectual connections that existed with the people in the department continued outside of the school setting. Crystal cited graduate student weekend retreats and outdoor activities among graduate students and faculty in her department. Both Dale and Nell talked about university intramural sports teams organized among the faculty and graduate students in their department. On the other hand, Maureen and Lena talked about outside involvements that were not linked to their departments (both women were involved in community clubs and Lena was an active member of a local church).

Visibility and Guidance

Nell said that during her first year in her program, when she was a master's student, she was already treated as a senior graduate student: 'Professors kind of treated me like I was in the Ph.D. program. You know, giving me opportunities to work on lots of research and stuff.' Dale and Eve both referred to research opportunities with faculty members early in their doctoral programs.

Visibility for participants also included more than research. Greer described a situation where a faculty member observed her teaching: 'He came to my calculus class this semester. He observed for I think 15 minutes. And afterwards he came up to me and he says, "Can I have a copy of your materials? They seem to be better than mine."'

All the women mentioned peers who offered encouragement in the program, and many talked about discussions with peers who provided connections to potential faculty mentors. Eve said that several of the senior graduate students in her program took notice of her struggling during her first year:

> It wasn't enjoyable and then, um, (pause) the peers here helped me realize I wasn't alone. They definitely made sure that − one of the advisors is an advocate of those of us who are kind of floundering out there − they made sure that she heard about me and so she came to my rescue.

Crystal noted two different communities of graduate students during the years she had been a graduate student − a past community of students, to which she felt membership, and a 'new' community, to which she did not feel membership. She felt a separation and *in*visibility from the new community of graduate student peers, which was in contrast to her past com-

munity of graduate student peers. In a more extreme instance, Greer talked about her perception of the complete nonexistence of community in her department, which she linked to her feeling that the graduate students were 'invisible' and left 'to flounder' until after passing the doctoral exams.

Moral Support and Encouragement

Maureen said that she decided on her program because of the supportive environment offered by the faculty:

> I feel like there are a number of faculty that are really great to have worked with. That I really enjoyed working with, that really pushed me but were really supportive. I think that that is something that is really important to me. Because I can handle, um, a demanding academic environment if I feel like there's support. And I think that gets back to, like, me not choosing certain schools for my master's in math or even a Ph.D. program in math because back when I was 22 I wanted to have a place where I would feel challenged but feel supported.

After a very difficult first year, Eve talked with emotion about the support and encouragement she got from a community of peers and from her advisor:

> There is no doubt. I'm finishing this program, and I am getting my Ph.D. I'm saying that last year there was doubt about a lot of things. Not just school. So um (pause) now I've got (pause) um (long pause) a fabulous advisor. And amazing peers too, um (pause) − 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?' And there's no way I can fail with that kind of support.

Crystal spoke similarly of her past community of graduate students − holding one another up in and out of classes they took together. Sue talked about support within her community of 'math ed. graduate students' and remarked on an absence of community and support with the students in mathematics courses she had recently taken.

Mentoring and Role Models

Nell spoke of research mentors − several faculty members with whom she had worked closely on research. She admired their research and appreciated that they treated her as a future peer, recommending that she work on independent research projects early in her coursework:

> [Recently several professors] got a call for papers from some folks in the communities and they forwarded it to us. And just the fact that we are doing enough to encourage us to submit our paper, I felt like maybe I do have something to offer the field.

When she chose her doctoral committee shortly after, she asked those she saw as role models to lead her dissertation research.

Crystal cited a professor who was a longtime mentor and friend in her program. He offered support and encouragement about her emergence as a member of the scholarly community. His words of encouragement marked a moment in which she felt she could complete her dissertation:

> He looked at me and he was like, 'You know, you get to this point in your dissertation process where you realize that you're good enough and that you have a right to be at the table. You have a right to share your ideas and they have a right to be there just like everybody else's.' Then he said, 'The way you walked in and greeted me today, you're real close. And about the time that you figure that out is about the time that you graduate.' So I would say that when he pointed that out − that's probably when I started to be more aware of what was going on. It's an inside job. The Ph.D. is an inside job.

Lena talked about developing close relationships with faculty mentors, spending time with their families and getting to know them personally. In particular, one friend in the field supported her through her struggle with her doctoral exams. In addition to fighting for Lena's rights in the department, she invited her into her office to offer emotional counsel and friendship throughout the process.

Teaching Quality

Sue explained that one of the primary differences between her master's degree program and her Ph.D. program was the classroom support she received in her Ph.D. program. Dale mentioned positively the idea of professors' 'engagement in their classrooms' and that it was what she 'favored.' Crystal also talked about her need to be acknowledged as a novice in the classes she took. She told a story about asking a question one day in a mathematics class and feeling the professor did a good thing when he replied, 'I can see why you would be concerned with that as a beginner.' She commented that the professor's response made her feel validated as a mathematics learner.

Dale discussed classes she found to be well-executed. A mathematics class she took her first year surprised her:

> My teacher had an unusual teaching style, particularly for an upstairs teacher. Those are the math people as opposed to math ed. people, who are all down here. And she had a style where she had these worksheets she would hand out and everybody was in groups. And you have the same group all term long. And you would work on the worksheets and you would jointly post homework problems up on the board and things like that. So she was really pushing the group dynamics and helping each other. She actually did not teach very much in that class...I really liked that class.

Dale also mentioned that having the variations in professors across both

areas influenced the development of her own teaching. In particular, a mathematics education class with a problem-solving and discussion format helped shape her teaching style.

> That just kind of gave me a new perspective about what teaching can be like and I realized that when you lecture, it's boring. And when your students are engaged, its fun. [It] opened up my eyes to the world of Math Education and what it could be. And I began to change who I was as a teacher because of it.

Crystal commented that she disliked a professor's class because she experienced little depth in the content:

> I can't stand her teaching style. (Laughs) It is so the antithesis of everything I'm about as a learner. I find her stuff to be busy work...When I had her the first time, I just didn't do the homework because I thought it was stupid.

Balancing Roles

Maureen spoke with intensity about her frustration with her inability to balance her professional life as a scholar with several interests. She put these aside while writing her dissertation and was struggling with whether that meant she had given them up. She said, 'Well, can you still call yourself something if you haven't touched it in three years?'

At the time of her interviews, Sue, who was also a community college instructor had begun a job share with a fellow community college instructor that was allowing her to take more than one class in the math department for the first time since beginning the program three years before. When approached several months into the next semester she was feeling a schism between the two. She said, 'My primary concern lately has been an apparent disconnect between my academic work and my professional work...I feel I have had to sever my two lives in order to survive.

Crystal commented, 'I think my grades have been indicative of my ability to maintain a life. Because I don't have all A's. I have an occasional C here and there. It's been hard.' She also commented that after her first year of graduate school she was able to reincorporate some important aspects of her personal life:

> I still managed to do a few things...I have to make a concerted effort on a regular basis [to nurture myself]...I'm borderline crazy as it is. Um, I tell you I would be crazy. No I think − I think I would be miserable. I really would. And I don't know if I would − if I would really be here.

Lena felt she had learned to balance the different roles in her life: 'wife,' 'mother,' 'fancy free' person 'on a date with my husband,' and graduate student completing a dissertation. She commented that learning how to 'compartmentalize' her life was essential:

> I think the biggest thing for me was my priorities changed...I think,

'Now, I've got four hours and I'm going to do the best I can in these four hours.' Because at the end of the four hours my attention goes 100% somewhere else. And that's something that some people never learn... But when I'm a mom, I'm a mom. And when I'm working on my dissertation that needs just me time...So, the boundaries don't blur as much as they used to.

Intellectual Ability

Greer admitted a low point of her first year in a mathematics Ph.D. program − and what ultimately encouraged her to seek out faculty members in collegiate mathematics education − occurred when a mathematics professor commented on her abilities: 'He said, "...Not to worry, you are not stupid you are simply slow." I have actually come to conclude that may have been a compliment...and actually, he quite regularly calls people stupid.'

Nell had very different experiences with people commenting on her intellectual ability. She spoke of people's surprise and disbelief when she struggled and had misunderstandings about ideas. She remembered a time when she asked a mathematics professor a question and his reply was an astonished, 'You have a question about that?!?'

Lena's comments about intellectual ability focused on academic performance, and particularly judgments she felt others made about her. She also mentioned there was 'always a smart kid,' and then noted she was not the 'smart kid.' She recounted her struggles to pass her Ph.D. comprehensive exams:

> I was struggling with how to do it, how to get through this process... Every person that I talked to about my comps said, 'We're sorry, if you can't write, maybe you don't need to be a professor.' You know, someone said those words to me....Everyone seemed to indicate that the something wrong was me.

Dale referred to Nell's intellectual ability several times, calling her a 'superstar,' her 'friendly nemesis,' and saying 'she's naturally smart.' Talking about herself in the Ph.D. program, Dale said, 'I would like to prove that I can be just as smart as her.' Eve also compared herself to a peer who had been in the program several years longer than she had:

> She is definitely not of my caliber. She's more advanced. She's proven herself. There is not one person in this department that would question her ability as a researcher or her ability as a teacher...or her ability to finish her degree. Everybody here is sure it is going to happen. Me? That's not how they feel about me. I still have stuff to show.

Maureen reflected on her own abilities in mathematics classes:

> I wouldn't say anything or assume most of the time that I didn't know the answer − because I always felt like 'I don't quite understand what is going on here.' Sometimes I would think that I had a clue about what

was going on, but most of the time I didn't quite understand what was going on. And I would just have to go home and work it to myself and then try to memorize things. And then I could work with other people − so I would have a better understanding of what I was talking about when I would work with them.

"My Teaching"

Nell spoke of connections between her classrooms as a learner and her classrooms as a teacher. A middle school teacher prior to graduate school, she had worked under an emergency credential to begin teaching and saw graduate school as an opportunity to build upon what she had been doing in the junior high school classroom:

> A lot of the way I taught was me just inventing how to teach based on what I thought would work for middle students because I never got formal training. So one thing I really liked was [when the courses] were taught by people that taught very similarly as I did. It was a kind of fun experience as a learner. It was more constructivist-based. Because what I did was just made up on my own, it was interesting to see if my instincts were right. But also how to revise them to be more effective. I really enjoyed being in that position.

Eve, who taught while working on her master's degree, found teaching during her first year in a doctoral program quite different, demanding of her in ways she had never anticipated. She commented on her struggle to find balance between her work as a student and teaching a course with multiple sections led by a course captain. Regular meetings of all the instructors for the course confused and concerned her. She found herself rethinking how she taught, but doing so was uncomfortable for her.

Sue was enthusiastic about teaching a wider variety of courses as she progressed in her career. Her initial motivation for seeking the Ph.D. in collegiate mathematics education was to do just this:

> I remember having that conversation with [a professor], saying, 'Okay the reason why I'm here is that I might not want to teach at the community college level forever.' At the time I was thinking I wanted a degree so I could maybe teach at a four-year college. I wasn't really interested in university teaching. I was interested in teaching; I just wanted to teach more of a variety of courses.

Crystal had recently submitted job applications to universities, where she reflected on her teaching philosophy. Having spent several years as a research assistant, she had not taught since her first year in the doctoral program. She decided, 'I think the first two years I am going to spend figuring out who I am as a teacher given the growth and development that I've accrued.'

Self as Scholar

Dale, Greer, Nell, and Sue were at points in their respective programs where they talked about themselves as students in the classroom with respect to preparing for doctoral exams and choosing an advisor to lead their future dissertation research. These four women also mentioned connections between what they were doing in their teaching classrooms (i.e., in the classes where they were instructors) and in their learning classrooms (i.e., in the classes where they were students).

Greer, who was preparing to leave her collegiate mathematics education program for a similar doctoral program, was frustrated that in not passing her mathematics doctoral exams she was unable to move forward with mathematics education. She had taken a mathematics education course the previous semester and talked about how she started linking her teaching experiences to future avenues of research. Sue, also in the midst of taking her doctoral exams, was enthusiastic about tying together her work with community college mathematics students and the research she read about in her mathematics education classes.

Dale talked about extending a research apprenticeship to her dissertation work. She spent several years working under a faculty member on a grant project and found the goals of the research to be close to her own research interests.

Crystal discussed her dissertation research with respect to a description of the process, her current progress and her thoughts about finishing the project. She commented that the process of completing her job portfolio provided her with a different perspective on finishing her dissertation:

> I'm like, 'Oh my God. I can, like − go do something. I can make a difference instead of being a bump on a log reading a book' ... Completing the dissertation just went from being a destination to a starting point for me in the last two weeks. All of a sudden it really is just a stop on the road.

Maureen talked about her need to balance the new and different responsibilities she was facing: In describing her frustration at having to set aside some of interests, she said,

> I haven't had the chance to actually start trying to write up any research after my dissertation. And if I want to fit that in there, I start to feel like...I'm not sure. Because I feel like you start playing that game to try and get tenure, or whatever you're doing, and you know, it's like another 5 years or 6 years of your life where you're trying to take on this, this, this, and this. You know, devotion to your university or your department, plus your research, plus your teaching.

Future Possible Self

Eve stated that moving into a collegiate mathematics education doctoral program related to her desire for community involvement at the time of her

decision and the knowledge that she would continue to need it in the future:

> I'm a very social person and the lack of social connection I felt sometimes was just too much. I woke up one day and I was like, 'I don't want to be peers with these people [in the mathematics department of her master's program].' I didn't want to sit in a room all by myself because that sucked...I would sit in a room all by myself working on problems. Didn't work out, go see the advisor, they crap on me a little bit. You go back and work on this problem. I mean nobody is there; you are alone.

Nell had not thought about returning to graduate school until the principal at the junior high school where she taught suggested it:

> He said, 'Well the problem with people like you was that, you know, well you get bored. So if you want to go back to grad school or something somewhere down the line and do research'...I hadn't really thought about it. I mean I like school and I maybe I would go back to school at some point but I hadn't given any thought to what I was going to get.

Maureen spoke candidly about sacrifices she had made in recent years, how it had affected her current self, how she wanted to see herself change, and how her physical location played into her future self. Greer talked about herself in the near future. Specifically, she talked about her options for the following fall semester, which included applying for community college positions as a mathematics instructor, teaching high school mathematics, and the possibility of joining a collegiate mathematics education Ph.D. program at a university in another state. One of her future selves included being involved in scholarly activity, which was contingent on where in her professional time line she might move to another Ph.D. program in collegiate mathematics education.

Lena reflected on how she saw herself using her degree:

> Research that I've done, I've liked it. The only other thing that I've enjoyed is to work in the school district. I think it would be fun to be some kind of state liaison for education, for math education. I would probably foresee that being tied to a university. But I, as a career, I, I mean, I wanna make this my career − as opposed to just some job.

In discussing what she would be doing five to ten years into the future, Dale talked about herself with respect to the hypothetical ages and activities of children who were not yet conceived at the time we spoke.

> By five years, I actually really hope that I have kids by then...I see myself doing part-time work...Ten years from now, if I had a kid now the oldest would be ten. If they were in school, I would have a little bit more time. So, while I had little kids, maybe one class a term. But kids in school, maybe half-time, it would more possible − I would be involved in things like curriculum and development. And play a bigger role because I wouldn't have kids around.

Discussion

The findings of this research indicate three important points for readers to consider. Results indicate that the initial seven 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. That is, the seven aspects of experience appeared across the experiences of the eight women, thus establishing a connection between women in collegiate mathematics education doctoral programs in mathematics departments and women in doctoral mathematics programs. However, these seven pre-existing categories failed to fully characterize the nature of the women's experiences in this study. Therefore, the research findings also indicated a need for the expansion of existing categories in the literature with the identification of three new categories. All focused on the participants' self-reflections, each of the three new categories appeared across the experiences of all participants. Together, these 10 categories were the key notions that women in mathematics education Ph.D. programs used to represent their experiences. With the addition of the three new categories, the need to refine the characterizations of the 10 aspects of experiences emerged, particularly in regards to highlighting the interconnectedness of the categories.

Aspects of Experience − Necessary

Similar to the literature, community emerged as an important aspect of the women's persistence in their doctoral programs. In general, participants' comments about community involvement included communities within their respective departments and in settings outside of school. This included a sense of community among graduate students, as well as a perception about their membership in the department among the faculty. More specifically, discussions pertaining to communities within the mathematics department included communities and sub-communities of graduate students that were temporally determined (as in the "new" and "old" groups), those that were locationally situated (either as a result of groups of graduate students sharing office space or groups of graduate students taking classes together), as well as social communities that included studying together, offering support and encouragement to one another personally and professionally, and friendships that existed outside of the school setting. These also included the existence of communities among graduate students and faculty within the department.

Participants felt visible when faculty members either took note of their presence in the department as junior colleagues, or noted their research interests and 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. Additionally, comments about visibility and guidance among the participants referred to community-building interactions with graduate student peers in their departments. The women also talked about visibility and guidance from professional mentors outside of their departments − people who offered encouragement at various times during graduate school. However, as one progresses through the doctoral process, it may also be that visibility and guidance separate and that visibility becomes more about acknowledgement as a near-peer (as evidenced by Crystal) and later, once graduated (as in the case of Maureen), as a peer.

All eight women described influential people (family, friends, peers, faculty members, senior colleagues) who offered support that ranged from early encouragement to pursue a graduate degree, to help in learning to teach, to encouragement to continue in a Ph.D. program. The most frequently mentioned aspects of support and encouragement were stories about peers, friends, and, in particular, faculty who offered scholarly support and encouragement about their progress in their programs and about their research.

Mentors and role models were faculty members, senior colleagues, or family members who offered advice, encouragement, or leadership, and were often someone in the field the participant admired. These individuals served as an academic guide, a research mentor who was either a leader in a research activity or who served as a model for the participants' own future independent research endeavors, were champions for the success of the graduate students in their departments, or offered personal encouragement to the women throughout graduate school. Similar to the research literature, there were very few references to people who were named as mentors or role models. Instead, the women commented on traits of different individuals they admired and modeled themselves after. Therefore, it may be that instead of seeing people they admired and wanted to model wholesale, the graduate women in this study saw certain *attributes* or *approaches* in multiple people. That is, there may be a few single role models and multiple people who serve as *roles* models.

The women all discussed their experiences, as learners, of college teaching. They talked about teaching delivery in mathematics and mathematics education classes, which included comments about types of engagement that professors seemed to have with the students. These ranged from 'warm and fuzzy' and 'hands on' (terms used by Dale and Nell) to 'lecture' and 'pontification' (terms used by Crystal and Dale). They also referred to teaching quality in terms of their perceptions about feeling supported in the classroom. Such support included comments about experiencing encouragement as well as thoughtlessness from professors. Additionally, the women critiqued the chosen styles of teaching for their classes, often comparing the styles of teaching in their mathematics classes to the styles in their math-

ematics education classes.

Consistent with the graduate students in the existing literature, the women frequently discussed their need to maintain balance between being a graduate student and other life roles. This balance ranged from expressing a need to negotiate time spent on the graduate program with responsibilities in parenting, significant others, having 'a life' in the community outside of the university, and an outside professional life, to a need to balance roles within the mathematics department, including the demands of various classes the women were taking or balancing taking classes, teaching classes, and working on research projects. In addition to the various roles needing balance in their lives, the eight women also talked about different aspects of their lives that might result in their feeling balanced or imbalanced.

Loosely defined in the existing research, I sought to clarify the use of 'intellectual ability.' In general, discussions fell into three categories. *Judgments by others* refers to another person's perceptions about a woman's intellectual ability, including things said about her intellectual capacities. Remarks included positive statements offering encouragement to continue her graduate education, comments expressing disbelief that a topic or course would be difficult or confusing for her, and negative statements about her ability to succeed in a topic, course, or program. *Judgments about others* refers to the perception a woman had about the intellectual ability of someone else, usually about fellow graduate students. These included comments comparing herself to another graduate student or referring to the academic performance of a peer, often followed by a remark linking performance to that other student's innate ability. *Judgments about self* refers to the perceptions a woman has about her own intellectual ability. She may have talked about her academic performance in classes and how that reflected on her capabilities. At times this reflection was also related to a comparison of oneself to others.

Aspects of Experience − But Not Sufficient

While the categories from the existing literature all appeared in the data of this study, other data was unaccounted for and required the formation of new categories. The first of those, *"my teaching,"* emerged as the women talked about teaching mathematics and its importance in their decisions to pursue the Ph.D. in collegiate mathematics education. These included reflections on their teaching philosophy and practice, comments about their teaching being an important aspect of how they thought about their learning in mathematics and mathematics education classes, and discussions about how the experiences in those classes influenced their teaching. Largely absent, however, was discussion of what others said about their teaching (e.g., from having observed it).

The second new category, *self as scholar* emerged as the women reflect-

ed 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 still completing coursework and not yet focusing on research (Dale, Eve Greer, Nell, and Sue) talked about themselves as learners and the relationships they developed with other learners in mathematics and mathematics education classes. These relationships included small classroom communities that developed, as well as situations where the women acted as leaders or teachers for the other students in their classes. The women who were further along in their respective programs and no longer taking classes (Crystal, Lena, and Maureen) talked more about their experiences as researchers. Looking into the future beyond the dissertation, they talked about preparing for their future careers, which included networking and presenting at conferences, as well as considering what it might be like to be a faculty member who would balance the different responsibilities associated with that role. That is, self as scholar is about growth, over time, from viewing oneself as a student in the classroom to a researcher − a process that is achieved through close work with senior peers and mentors. This was quite different from the reports of mathematics graduate students (Herzig, 2004a), most of whom saw their graduate experience as two distinct parts: student until exams, independent researcher after exams.

Initially noted in passing in Herzig's (2002, 2004a, 2004b) research as the way graduate students conceived of their futures, the idea of *future possible self* (a title I borrowed from the research of Markus and Nurius, 1986) emerged as a powerful meta-category across the others for all of the women in this study at all times in their graduate school timeline: past, present, and future. They often mentioned how those experiences projected into the future and affected different aspects of their lives. In particular, future possible self emerged in several ways. *Past future possible self* refers to a woman's discussion of times in the past when she thought about her future and who she wanted to be, what she saw herself doing, the physical locations in which she saw herself, and reflections about what the meant for her goals. *Present future possible self* refers to a woman's reflections on the future based on who she was at the time of the interviews. She talked about who she currently was and who she saw herself becoming. *Future future possible self* refers to a woman's discussions of future possibilities that were based on the outcomes of other future possibilities. That is, these were possible selves or paths that emerged as a result of potential future selves or future chosen paths.

Aspects of Experience − Mutually In*exclusive*

Whether they spoke about their community involvement outside of their respective mathematics department, someone else's teaching (professor or peer), or any other of the ten aspects of experience, comments from all of

the participants were also often strongly connected to one or more of the other aspects. That is, the 10 aspects of graduate student experience for women outlined as the main results of this research are not discrete or mutually exclusive. It is likely that it is not possible to discuss any one single aspect of experience without (explicitly or implicitly) commenting on at least one (and usually more than one) other aspect of experience. Therefore, these categories must be understood as non-linear in a way that mirrors the complexity of the participants' lived experiences.

Briefly noted already is the connection of future possible self with the other nine aspects of experience. This was unsurprising given the attention to the social, locational, and *temporal* aspects of the women's experiences incorporated into the idea that possible selves grow out of past and current selves, as well as observations of and comparisons to past and current others (Markus & Nurius, 1986). Threaded through their discussions of community, visibility and guidance, moral support and encouragement, mentoring and role models, teaching (others' and their own), balancing roles, intellectual ability, self as scholar was a self-reflection across time. All points across the timeline of each woman's graduate education included reflections about how their experiences impacted their perceptions of themselves (current and future).

Additionally, the women talked about the importance of having community with peers and faculty within their departments, as well as outside of their departments. When coding the interviews for aspects of experience, many segments of the interviews that were coded as "community" were also coded as one or more of "visibility and guidance," "moral support and encouragement," and "mentoring and role models." As it became increasingly difficulty to describe each aspect of experience without using the language of the others, it was important to note the components of community for the women appear to be personal and academic visibility and guidance, moral support and encouragement, and mentoring and role models. That is, although identified as separate, independent aspects of experience in the research literature on graduate students in doctoral mathematics, it is reasonable to conjecture that these three categories are, in fact, dependent aspects or subcategories of *community.* A full investigation of the nature of this nesting, however, is beyond the scope of this report.

There are also obvious connections between the categories of teaching quality and "my teaching." Though not addressed in the interview protocol, participants spoke of identifying aspects of the teaching they encountered as students in the classroom that influenced their own actions as mathematics teachers. In ongoing collaborative research, the author has worked with peers to develop an interview protocol explicitly directed at asking questions about the graduate students' teaching and learning related experiences in the classroom in graduate school. In addition to offering further refine-

ment of each of the two categories, it is serving to shed some light on the connections and overlap between the two.

Conclusion

Taking the opportunity to engage with women in doctoral programs in collegiate mathematics education and beginning to build a body of research that investigates the nature of graduate student experiences in these programs is beneficial in a number of ways. In particular, this research offers information to students, professors, directors, and administrators in mathematics departments about graduate women's experiences of the environments that exist within their departments. In particular, as women are the majority group in collegiate mathematics education and a minority group in almost all mathematics departments in the United States, there may be a cultural conflict between the values, goals, and objectives of someone who wants a collegiate mathematics education Ph.D. and those at many university mathematics departments.

Interviews with more graduate students, including men, in collegiate mathematics education programs housed in mathematics departments will facilitate deeper, richer understanding of the cultural environment of doctoral collegiate mathematics education programs. Additionally, returning to mathematics programs using the expanded framework of this research will assist in further refinement of the literature on graduate student persistence and attrition, particularly among women, in mathematics doctoral programs.

Increasing the breadth of research on programs in mathematics education housed in mathematics departments offers potential graduate students, particularly those who are interested in mathematical careers other than as research mathematicians, information about the various avenues that are available to them. A growing employment venue for those with Ph.D.s in collegiate mathematics education is in university mathematics departments, where responsibilities include not only teaching classes in mathematics and mathematics education, but also participating as leaders and researchers in the teaching and learning of undergraduate mathematics (Reys et al. 2001). People in such positions, in turn, can help better prepare the next generation of K-16 mathematics teachers, mathematics educators, and research mathematicians.

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