

an exploration of the transition to graduate school in mathematics

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In recent years, researchers have given attention to the new mathematics graduate student as a mathematics instructor. In contrast, this study explores the academic side of the transition to graduate school in mathematics—the struggles students face, the expectations they must meet, and the strategies they use to deal with this new chapter in their academic experience. I will identify several resulting themes—Isolation vs. Community, Academic Relationships, Role of the Department, and Realizations of Self—from semi-structured interviews with mathematics graduate students designed to explore multiple aspects of the academic transition to graduate school. I will also use the social theory of legitimate peripheral participation (Herzig, 2002; Lave & Wenger, 1991) to discuss potential implications for graduate students.

Key words: graduate students, academic transition, semi-structured interview, legitimate peripheral participation

The academic transition from undergraduate to graduate school is undoubtedly a significant one in even the best of circumstances. During this transition, students often face new research expectations, increasingly abstract content, and an unfamiliar geographic location. Furthermore, in mathematics departments, many graduate students are also expected to teach or assist in undergraduate courses as graduate teaching assistants. Park (2004) noted that graduate teaching assistants can struggle with their new dual status as both learners and instructors, while Bozeman and Hughes (1999) referred to these experiences as an “abrupt change of status” (p. 347) for these students. Despite exemplary undergraduate records, students may have difficulty adjusting to their new environment or overcoming academic setbacks, such as insufficient prerequisite knowledge or an inability to meet professors’ expectations.

Beyond diminishing students’ self-esteem or their desire to complete their graduate study, these transitional stumbling blocks impact mathematics departments: Students’ struggles with the transition to graduate mathematics may negatively affect program recruitment as admissions committees are less likely to admit applicants with similar backgrounds in the future. Retention is also impacted across the discipline as promising students may incorrectly assume they lack mathematical ability and leave the field forever. Finally, these struggles can affect the representation of women and minorities in such programs, as these groups are less likely to find the support structures they need to survive graduate school (Bozeman & Hughes, 1999).

To provide a foundation for future work in research on graduate students, I sought to establish a clear picture of what happens during the transition to graduate school in mathematics. This paper reports results from a larger, interview-based, qualitative study designed to explore the academic transition to graduate school in mathematics—the struggles students face, the expectations they must meet, and the strategies they use to deal with this new chapter in their academic experience. In particular, I started with the following exploratory research questions: What happens during the academic transition from undergraduate student to graduate student in mathematics? How do professors’ expectations of new graduate students’ mathematical knowledge affect students’ success? How do new graduate students in mathematics adjust to the rigors of graduate school and/or compensate for prior knowledge deficiencies? How do attitudes, beliefs, and relationships play a role in the success of new graduate students in mathematics? I

hope that this research will provide a more accurate picture of graduate student preparation for and experiences in graduate school in mathematics; then, we can work to modify resources for prospective and current graduate students accordingly to help make the transition as smooth as possible.

Background

Many academic transition points, such as the transition from secondary to tertiary mathematics, have been studied extensively as stakeholders have tried to narrow the achievement gaps among various groups of students. For instance, Selden (2005) discussed this transition to collegiate mathematics, noting that new college students must often reconceptualize ideas from previous mathematical training (such as the idea of a tangent line) in order to incorporate them into the new, demanding educational structure they have encountered. As another example, Kajander and Lovric (2005) detailed McMaster University's efforts to address this transition through surveys of students' mathematical backgrounds, course redesign, and provision of a departmental review manual to enable students' voluntary preparation for their mathematics courses. They noted that students' motivation, ability to delve beyond surface learning, and secondary school preparation in mathematics were all key to the transition process. Transferring the ideas from these two studies to the transition to graduate school in mathematics identifies several potentially relevant issues in this transition process: undergraduate preparation, ability to both reconceptualize prior knowledge and dig deeply into new mathematical material, and a "bridge" review process prior to graduate work. However, other factors may impact the transition to graduate school that are not found in this body of work.

Despite research on other transition points and recent work devoted to the new mathematics graduate student as a mathematics instructor (e.g., Border, 2009; Luo, Grady, & Bellows, 2001; Speer, Gutmann, & Murphy, 2005), little work has been done with other areas of the transition to graduate school, such as the impact of academic or personal issues on the transition experience. Related work has been done by Carlson (1999), who explored the mathematical beliefs and behaviors of "successful" graduate students; she found that persistence, high levels of confidence, and the presence of a mentor during key periods of mathematical development all played a role in these students' "success." However, while factors affecting retention and student success certainly impact students' experiences in the first months of a graduate program, they are not sufficient to define the transition to graduate school. More recently, Duffin and Simpson (2006) reported on interviews with Ph.D. students designed to explore the transition from undergraduate to graduate work in mathematics in the United Kingdom's educational system and concluded that both undergraduate and graduate education could be modified to smooth this transition for different types of learners. Despite this work, no clear picture of the transition to graduate school in the United States exists.

One theoretical lens through which to view research on graduate students—legitimate peripheral participation [LPP] in communities of practice (Lave & Wenger, 1991)—shows great promise. Lave and Wenger (1991) provide LPP as "a descriptor of engagement in social practice that entails learning as an integral constituent" (p. 35). They also describe LPP as "the process by which newcomers become part of a community of practice" (Lave & Wenger, 1991, p. 29). In 2002, Herzig applied this framework to a qualitative interview study examining persistence in graduate school in mathematics. In this case study of one mathematics department, Herzig interviewed both current students in the doctoral program and some who had left the program, as well as faculty members in this department, to investigate factors influencing doctoral student persistence and attrition. Herzig found that legitimate peripheral participation both in

departmental life and in the field itself encouraged persistence in a doctoral mathematics program. Although this framework promises to enlighten research on graduate students more broadly, further work is needed to determine the phenomena involved in the graduate education of mathematics students. Thus, to further research in this young area, a more complete description of the transition experience is needed.

Research Design

This paper focuses on a subset of the data from a larger, exploratory, single-case study designed to delve into the in-depth meanings of one mathematics department's experiences with the transition to graduate school. To fully explore these experiences, I adapted elements of Herzig's (2002) design, conducting interviews with both graduate students and faculty members in one mathematics department. Semi-structured interviews with both graduate students and faculty members were centered around the research questions given above, with probing questions included as appropriate. The student interviews (median length 1:01:48), which are the focus of this paper, allowed me to ask specific questions about participants' experiences surrounding the transition to graduate school, while the faculty interviews (median length 1:03:00) were designed to provide a new perspective on the same aspects of the transition experience. Faculty interviewees came from a list of those who had recently held positions related to graduate students—such as Chair, Associate Chair, Graduate Director, or core course instructor—and who were willing to participate. This paper focuses on the graduate student interviews.

Graduate students in mathematics at a large, public, Midwestern research university were emailed and invited to participate in a brief online survey (eight questions; median length of completion = 0:02:50) to provide basic demographic information to aid in interviewee selection. All 13 interview participants were domestic graduate students who had taken core courses in the Ph.D. track at this university. [Fourteen students self-identified as meeting these criteria based on the survey. However, upon conducting interviews, it was determined that only 13 actually met study criteria; the other interview was omitted from the data presented here.] Of these 13 participants, six were male and seven were female; six had completed an undergraduate degree at this university; and year of program entry ranged from 2003 to 2010.

Interviews were audio-recorded and fully transcribed. I used an open coding procedure (Strauss & Corbin, 1990) to build a structure to this transition by merging preliminary codes to identify themes in the data. This structure is thus grounded in participants' views and in their words (Creswell, 2007), as demonstrated by the reliance on participant quotes as evidence throughout the presentation of results.

Results

In the interview excerpts presented below, student quotations are tagged with codes of the form Syz, where the "S" indicates a student interview and the two-digit number yz gives the identifier assigned to that participant. In this way, individual participants can be followed throughout the data presented. Within the student interview data, four main themes have emerged and are discussed below: Isolation vs. Community, Academic Relationships, Role of the Department, and Realizations of Self.

Isolation vs. Community

This section presents three ideas related to the contrast of isolation and community. Several student participants, including some who had completed their undergraduate studies at the same university, identified a feeling of isolation upon transitioning to graduate school. All participants

mentioned the impact of the academic and social community of their fellow graduate students. The idea of competition also played an interesting part in the sense of community that students experienced during graduate school.

Unexpected isolation. Seven of the 13 students reported experiencing an unexpected sense of isolation upon their arrival at this graduate program. For some students, this isolation was social in nature: “Especially in the first year, I would go home every couple weekends.... That was probably the biggest change for me, just being away from home, not having all my friends right there, like in college” (S02). Other students made similar comments: “The place that I came from was very stable, very supportive. I had tons of friends. I had a church where I knew lots of people. They supported me.... And I didn’t have that here. I didn’t know anybody” (S13).

These students explained their isolation as a function of the loss of the proximity of support structures such as family, friends, or other social systems. Ironically, even three students who had done their undergraduate work at the same institution also reported experiencing some social isolation upon entering this new chapter in their academic experience.

However, other students experienced a sense of isolation that could be better classified as academic in nature. For instance, when discussing a struggle with coursework during the first year of graduate school, one student made the following comments:

I didn’t expect to fall so far behind so fast. I wasn’t used to that. When that had happened in previous courses, like in undergraduate courses, there were always a few people that were right there with me. I could talk to people in the class... And in grad school, I didn’t see other people getting really, really confused. That’s not to say that there weren’t people getting really, really confused, of course. For some reason, I got the impression that everyone else was pretty up to speed with what was going on, so that made it more difficult. (S14)

This student went on to describe how these academically isolated experiences were followed by lower grades, lack of confidence, and an unpleasant feeling toward graduate mathematics. Together, academic and social isolation separated students from the sense of community they came to realize was instrumental in their ultimate success.

Role of community. Most student participants emphasized a specific role that community had played in their graduate experience. This role was often academic:

I would recommend just developing relationships with your classmates to support each other with your classwork. It helps a lot... to just talk about the material with them, and you’ll learn a lot. Some of you might understand some things, and you’ll learn a lot just explaining those things to the other students... I’d recommend developing that as early as possible. (S04)

Another student went so far as to make the following claim: “I work in groups so much now... I rely on other people, and that’s been a significant change. I know I could not get through graduate school by myself” (S05). Certainly, for a student pursuing a Ph.D.—and thus, likely very talented in the field—such an admission speaks volumes toward the importance of community in the graduate school experience. Clearly, having peers with whom to work through assignments and other content was crucial to these students’ success.

However, community fulfilled another important function—that of emotional and social support during the rigors of graduate school. One student commented on experiences with this dual role of community:

Study groups are great, because if you know something, you know it better by teaching it to someone else, or explaining the problem to someone else, and if they know something, then they can explain it to you.... And so, it helps to work out the kinks with other people.

And you also get that camaraderie of ‘Yay! We’re all in this together.’... That was one of the biggest things, I think, that really helped me get through a lot of the courses was just having that support circle of the study group. (S11)

Clearly, the support of a community of peers had a huge impact on these students. However, despite emphasizing this support, students often used the language of competition to describe their graduate school experiences.

Competition. Without prompting, five students specifically mentioned “competition” or “competitiveness” when relating their initial experiences in graduate school. However, these students were only rarely referring to actual competition between students for grades, attention, or any other endowment of status. More often than not, they were referring instead to the enhanced level of mathematical quality exhibited by their new peers.

There would be, even though we’re not competing against each other in a real competitive way, the competition as far as where you are in the class, you kind of realized that that was going to be, not so much like it used to be... We were probably all surprised that we weren’t at the top of the class when we were used to being at the top of the class. (S08)

There was actually a spirit of competition for the first time when I started grad school. It was very subtle. It wasn’t like everybody was fighting for grades or anything, but you can actually sit around and talk about, ‘How did you do on this thing?’ and ‘What did you guys do?’ and I think for the first time I was actually immersed in a mathematical culture.... For the first time I was actually sitting around having conversations with people about mathematics. (S01)

Clearly, these students had to adjust to the new “mathematical culture” they were experiencing, but they generally seemed to embrace this culture whole-heartedly.

However, for one participant, the idea of competition was all too real:

The competition in the classes with the other students was different [than in undergraduate]... Where I came from... the students were more supportive. There was a big study group. I had six or seven people who were in most of my classes as we all went through math majors together. And when we sat down and did homework, there were a minimum of four or five of us working on any given homework set at a time. And here, it could happen that way, but the people who were involved in these study groups here were the cream of the crop from where they came from. So, egos kind of got in the way a little bit more.... It gets a little harder. The study groups didn’t come together as well. It gets a little more competitive. Especially in one of the particular classes that I took that [first] fall, the professor... would rank everybody’s grades based on what they had done, and whenever there was a natural break, those would be the A’s, those would be the B’s, and if there was a big natural break somewhere else, those were the C’s, and so it really was a competition. If you wanted an A, you really had to beat everyone else. (S13)

Interestingly, S13 was the only participant in this study who was no longer pursuing a Ph.D. in this department, despite spending the first few semesters of graduate school enrolled in core Ph.D. coursework. While this evidence is anecdotal at best, it does seem to emphasize the importance of a sense of support amongst the mathematical community in graduate school.

Academic Relationships

Beyond relationships with their peers, students also encountered other relationships during their first few months in graduate school that had a great impact on their transition experiences. This section discusses the role of students’ relationships with content and with their (instructing)

professors and the ways in which these relationships affected students' overall transition experiences.

Relationship with content. Eleven of the 13 student interviewees discussed the increased difficulty they experienced in their initial coursework in graduate school. For instance, one student commented that “the amount of work expected from each of the courses is a little bit more than you might see in undergrad, either in the level of difficulty of the problems, or just the number of problems” (S11).

Furthermore, while all students acknowledged that they had expected graduate school to be “hard,” many of them also emphasized that they could not have anticipated the exact nature of the difficulty with which they were presented. One of these students addressed this phenomenon: “I anticipated an advanced difficulty level. I don’t guess you can really prepare yourself for that, though, until you actually do it” (S12).

For some, the new intellectual challenges presented by graduate school were exhilarating:

I remember my first week being very exciting, and very positive, because I got to be immersed in math, and go to all these different seminars, and hear all these words I’d never heard before, and see people talking about all these interesting things. (S10)

However, for others, this difficulty was overwhelming or burdensome, and they felt that professors’ expectations played a role. Student S08 mentioned lying awake at night, worrying because “sometimes I think [professors] thought that I should know more than I did.”

Other students had to compensate for specific prior knowledge deficiencies: “There were a few topics that I had to look up myself and teach myself in other courses because the professor expected that we already knew that, and I didn’t necessarily know that” (S11). But, sometimes lack of preparation spanned an entire course (most notably, topology):

I had never seen any topology at all, so having to come in to a graduate level sequence in topology, that was kind of a big shocker. I tried to prep myself with the undergraduate topology...the semester before I knew I was going to start that sequence, and it was a lot to try and prep yourself for. So, I didn’t really feel prepared in that area at all. (S13)

Students discussed compensating for under-preparation in content areas such as topology, linear algebra, and complex analysis. While most students found some way to cope—using the Internet, supplemental textbooks, peers, or instructors—with a lack of prior knowledge, these initial struggles with course content played an important role in students’ impressions of their transitions to graduate school.

Relationship with professors. Content was not the only area in which graduate students had to forge new academic relationships, however. Often, experiences with content were compounded by relationships with (instructing) professors, either actual or perceived:

I don’t think it was the material at first that was difficult, it’s just, it took me a while to adjust to new people. Back at my old university, I knew all the professors, and I knew what to expect.... I knew the style of my professors.... My biggest transition has been adjusting to the people. (S07)

I got the impression that everyone else was pretty up to speed with what was going on, so that made it more difficult. It made it so that I felt like the only person who could help me would be the teacher, and some professors are less approachable than others. Let’s just put it that way. (S14)

In the first quote, the transition to graduate school was compounded by the lack of familiarity with faculty at a new institution. However, in the second example, a sense of academic isolation among peers deteriorated into a true academic struggle when professors were not “approachable”

to this student. And while many of the relationship difficulties centered on mastering the mathematical content, other students struggled with the loss of interpersonal contact with professors they had experienced as an undergraduate student:

I was very used to working closely with my professors at {school}, because it was such a small school, which was quite a change when I came here... At {school}, I would be in their offices every afternoon talking to them about things, and here I don't go to my professors' offices all that often....We were kind of friends, so that was quite a change, too. (S05)

Nearly all students mentioned the importance of relationships with professors or the need for adapting to professors' teaching styles as a factor in their ultimate success in graduate school. These comments came in response to questions about professors' expectations, the ways in which courses had changed since undergraduate school, and even compensation strategies. Thus, professors seemed to play an integral role in multiple facets of the academic experience for these students.

Role of the Department

While professors certainly play a large role in setting the department's cultural standards and expectations, other aspects of the department also impact students' experiences in graduate school. The department's administrative roles—such as handling quality-of-student-life concerns, advising students, and assessing degree progress—also have a great impact on students' experiences with the transition to graduate school. While some of these roles are dependent upon the particular people or departmental policies involved, others, such as those discussed below, are general enough to have potential applications outside of this specific department.

Informing. All participants mentioned that they would have liked to have more information regarding issues ranging from tuition costs to teaching responsibilities, from paychecks to degree requirements, from health insurance to the amount of time and effort a doctoral program would require. Many students framed these comments in the context of course advising, saying things such as: “For the first two or three years, it just feels like you're kind of floating around. ‘Well, everybody takes these courses, so I'm just going to take these courses’” (S01). These students failed to see how to build their own degree plan around departmental requirements. Many (especially more senior) students wished information regarding these requirements had been more readily available or had been emphasized during mandatory advising appointments.

The lack of information was also strikingly felt in the area of research expectations. Several students wished that the idea of research, an explanation of the procedures and types of work involved, and the length and depth required by the research process had been introduced earlier in their degree. One student summed up these feelings this way:

If you're going to get a Ph.D., you need to want to do research. And, I don't know how that could be communicated, mostly because people coming out of an undergraduate [degree], they have no idea what it means to do research. That's an unknown. And I don't know that you could even instruct them as to what that is at that point. But, I think that needs to be communicated as quickly as possible to graduate students... so they can make the decision if they want to do it, or if they want to stop at the master's. (S06)

Other students were surprised at the active seminar culture in the department, their role in attending and presenting in these seminars, and the process of finding a research advisor. While systems of disseminating information to students vary widely among institutions, this was one area in which these participants saw room for improvement.

Mentoring. While students felt strongly about the importance of community during the graduate school experience, several wanted to take community a step further to combat the lack of information they received regarding the navigation of the graduate school experience. These students felt that a mentoring program for graduate students would have helped them with their transition to graduate school:

I've heard people talk about this, but I haven't seen it in place...doing some sort of mentoring program where you match a graduate student with an older graduate student and possibly a professor so that maybe graduate students don't feel quite so alone when they start. (S05)

Another student emphasized that this mentoring arrangement need not be terribly formal: "Not that we would need a mentoring program, but it would be nice to know someone that you could ask, or that was kind of assigned to you to talk to, or something" (S03). By putting community to work in even this relaxed way, these students felt that their needs during the transition to graduate school could have been met more effectively.

Realizations of Self

In addition to commenting on aspects of the department, culture, and content that impacted their transition experiences, many participants also commented on their own perspective changes or personal growth through the graduate school experience. While these took many different forms, two key realizations are discussed below.

Dedication. Eleven students emphasized the importance of being committed to and persevering through their degree program:

You have to decide you're going to do it. If you're wishy washy, it's over. I think that, just making the decision 'I'm going to do this, and I'm going to finish it regardless,' that's probably what you have to do, because it is going to be difficult, and if you're at anything thinking 'I don't want to put up with this kind of difficulty,' then you're not going to do it. (S06)

Overcoming the inevitable obstacles of difficult material, research struggles, and a new social and academic environment was quite a challenge for some, but their perseverance carried them through. One student described this perseverance this way: "Once I've committed to doing something, it's very important to me to follow through on it. So, if I encounter difficulty with something I've committed to, then I'm going to do my best to keep with it and succeed" (S04).

While dedication to the experience was important for all students, one student emphasized the primary role that perseverance played in ultimate success in graduate school. This student said, "If you really want to do this, perseverance is probably the biggest thing. I never would have been able to do this if I hadn't been resigned to figuring it out at some point" (S14). This student went on to say that "I didn't get by because of my knowledge of mathematics. That had absolutely nothing to do with it.... That was just kind of a by-product of the persevering" (S14). While mathematical aptitude is obviously important to obtaining an advanced degree in mathematics, this student felt that perseverance ultimately played a more important role.

Searching for a place. In addition to realizing the importance of sheer dedication to the degree, students also stumbled upon new perspectives on their relationships with academics and with life. When discussing their place within the "mathematical culture," students made comments such as this:

In undergrad, I was the top one or two or three students in the class, and then I felt like I was middle of the pack or less in graduate school....When everybody is interested, and

everybody's knowledgeable, it always happens that you kind of fall more towards the middle, or bottom. (S03)

Other students had to adjust their definitions of "academic achievement" or "success" in order to satisfy their intellectual drives or academic perceptions of themselves:

My attitude has changed a little, but I still have the attitude that 'Well, I might not be able to do as well as they do, but I can do enough to get through this and really learn and do well'. (S08)

I think of myself very much as an academic person....Throughout my entire life, I've always defined myself by my success in school.... I think that determination to keep that part of what defines me, to not let that go, helped me keep saying that I had to succeed.... The definition of doing well has gotten tweaked a little bit.... I stopped building everything on an A. To me, doing well didn't necessarily have to correspond to the grade anymore. But, I still need to do well. There's still that drive there. (S11)

For some students, graduate school meant defining a purpose or role in the greater world outside of academia:

Graduate school felt like a waste of time at the beginning. It was like, 'I'm just doing math. Who cares? What does this matter? So that, figuring out my place in society, I felt like I wasn't quite as useful as I could be. (S05)

This student went on to realize that graduate school did not have to serve as a placeholder between an initial degree and an ultimate career, later stating the following: "I've realized that my life is happening right now. I don't have to wait for it to start. It is going on, and I can find satisfaction and purpose in whatever I'm doing" (S05).

This sense of purpose was echoed in other interviews. Over half of the student interviewees explained that their life outside of mathematics helped keep them grounded or allowed them to balance out the stresses of graduate work. One student seemed to take this idea to heart particularly strongly:

The one thing that I have to keep coming back to is that this doesn't define who I am... I think a lot of people who are talented academically face that, like, 'Are we defined by our performance, or what? Who am I?' So, keeping it in perspective that this is not my entire life... that's helped a lot, because when it's not so all-consuming, I'm less stressed about it, and I'm able to learn and perform a lot better when I'm less stressed. (S12)

These students' realizations of themselves, their attitudes, and their level of commitment to their mathematical careers were clearly an important part of their graduate school experience and would have made a great impact on their transition to graduate school if discovered sooner in their academic careers.

Discussion

While many facets of the study of mathematics graduate students remain unexplored, this study took a qualitative look at the transition to graduate school in mathematics. The results section above used students' own words to describe the importance of community, academic relationships with new content and professors, the department's role in informing and mentoring, and students' realizations of aspects of themselves throughout the graduate school experience. In this section, we revisit the results in relation to previous work, with the theoretical lens of LPP, and in terms of participants' and other recommendations for departments and for students experiencing this transition.

Isolation vs. Community

Students clearly relied upon both the academic and the social support of their community of practice (here, the mathematics department at their university) to thrive in their initial graduate work. This is consistent with Herzig's (2002) findings that "participation in the academic and social communities of the department is a critical factor in doctoral student persistence" (p. 206) since initial success using this support would promote continued persistence in the program of study. Furthermore, Lave and Wenger's (1991) theory of the importance of LPP supports the idea that newcomers to a community of practice need to engage both with other members of the community and with tasks relevant to that community's work. In this way, both collaborating with peers on assignments or discussions of course material and socializing with those peers are a necessary part of the transition into the new academic community of graduate school.

Academic Relationships

For many students, an important part of the transition to graduate school was negotiating new relationships with professors and with increasingly difficult and abstract mathematical content. Beyond the horizontal sense of community mentioned above, students also need the vertical sense of community established when they are treated as "junior colleagues" (Herzig, 2002, p. 201) by faculty members. Spending time around these gatekeepers of the mathematical community helps students achieve both the mathematical ability and skill necessary to excel in the field as well as the social and cultural knowledge needed to feel like a true member of the mathematical community (Lave & Wenger, 1991).

However, social and cultural knowledge are of little use if a student cannot master the material needed to stay in a graduate program. Students often have to determine new ways to study and to process course material beyond those they used as undergraduate students (Duffin & Simpson, 2006). Furthermore, insufficient prior knowledge can cause the transition to be unbearable for many students. One remedy for this, suggested by S14, would be to have some kind of "Intro to Graduate Math" course or review manual during the summer prior to the beginning of graduate school. Such an idea has already been piloted at the secondary/tertiary transition level (Kajander & Lovric, 2005), although Kajander and Lovric (2005) noted that students' individual motivation to utilize review materials would play a key role in the success of such a program.

Role of the Department

Beyond what happens with mathematical content or course-related interactions, however, students must learn the "ins and outs" of succeeding in graduate school and in mathematical culture more broadly. Realistic expectations of the nature of the degree path (sets of departmental exams to be passed, paperwork required by various campus offices, average time to graduation) and of the research process can be gleaned while students participate in the community in legitimate, peripheral ways. However, many graduate programs in mathematics expect students to master prescribed content through coursework rather than encouraging them to "*think, act, and feel as mathematicians do*" (Herzig, 2004, p. 389). Thus, students in transition from undergraduate programs do not have access to these cultural forms of knowledge and can feel lost within the graduate system. Incorporating mentoring, which has been related to success in mathematics (Carlson, 1999), connects incoming students to the departmental culture via a vertical (advanced graduate student or professor) sense of community. These connections, combined with the sense of community among peers and the relationships with professors discussed above, could help students navigate the transition into graduate school more smoothly.

Realizations of Self

The students interviewed for this project strongly emphasized their dedication to, or persistence with, their graduate work. In 1999, Carlson also found that “persistence was the trait most frequently cited [by graduate student interviewees] as facilitating... mathematical success” (p. 244). Herzig (2002) noted that participation in “the academic and social communities of the department” (p. 206) played a key role in whether students persisted in their pursuit of a graduate degree. As noted above, the sole interviewee who had decided not to pursue a doctoral degree was one who had several negative things to say about the transition into the graduate program. While this could be viewed as an isolated case, we should also consider the role that transition experiences play in whether students persist toward the Ph.D.

Conclusion

As they progressed through graduate school, the graduate students interviewed for this study had to take on more and more tasks common to life as a mathematician. According to Lave and Wenger (1991),

Moving toward full participation in practice involves not just a greater commitment of time, intensified effort, more and broader responsibilities within the community, and more difficult and risky tasks, but, more significantly, an increasing sense of identity as a master practitioner. (p. 111)

That is, as students become more involved in the teaching, research, and service activities common to a mathematician in an academic setting, they form their own sense of identity as a mathematician. While this identity formation happens over time as students participate in a community of practice, early experiences with the transition help shape students’ view of the field and of “master practitioners” therein.

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